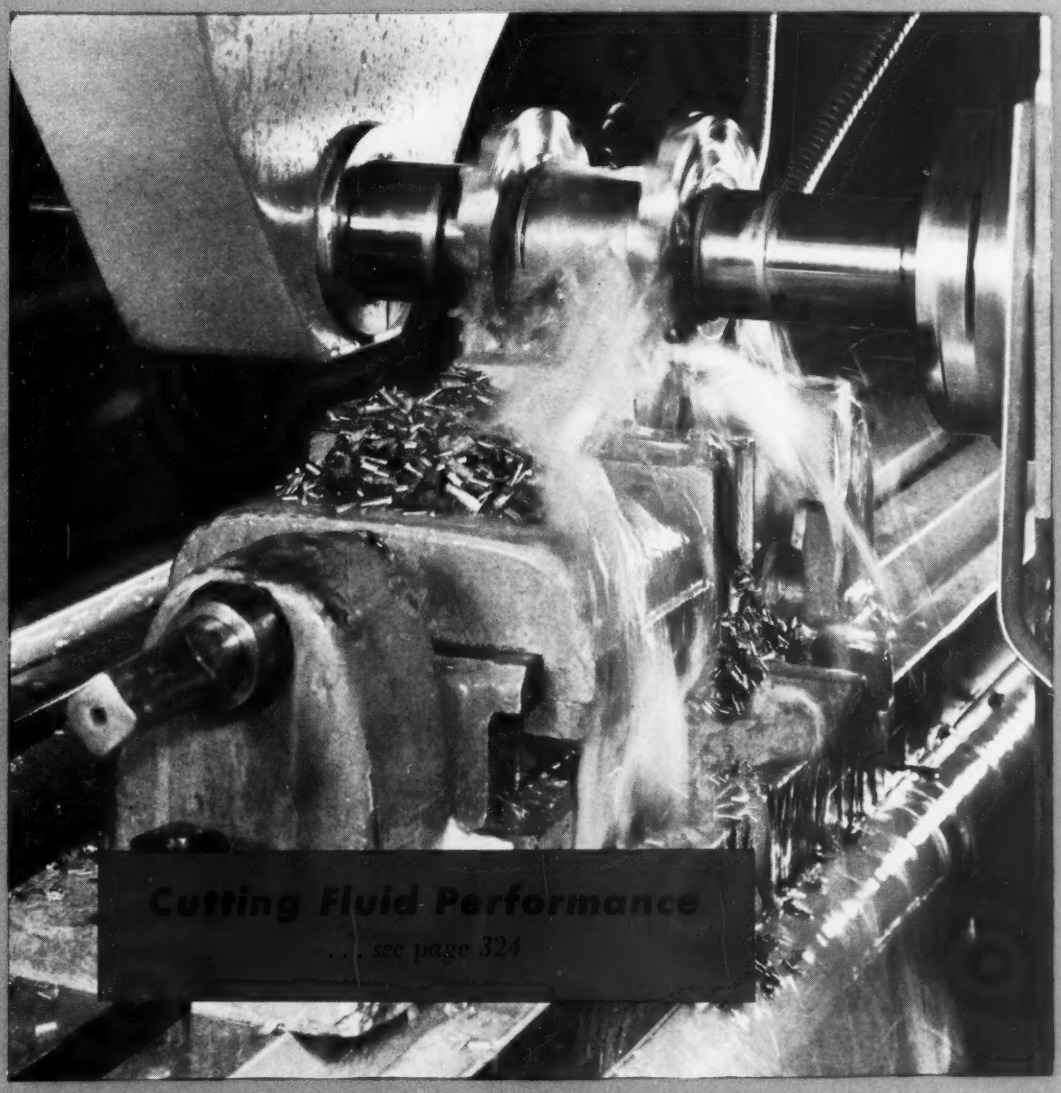
Vol 17, No. 7 July, 1961

LUBRICATION ENGINEERING

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE



JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

CLIMAX MOLYBDENUM

Molysulfide® News Digest

CLIMAX MOLYBDENUM COMPANY, a division of American Metal Climax, Inc., 1270 Avenue of the Americas, New York 20, N.Y.

RECENT TEST SHOWS MORE PROOF OF MoS_2's LOAD-CARRYING ABILITY

Grease Compounders Take Hard Look At Paste Type Concentrates

In a recent issue of NLGI SPOKESMAN, a prominent lubrication authority warns that in the future an increasing number of the newer machines will be greased "for life"—or for long lubrication intervals. He also says that as the industrial pace quickens and wages go up, it will be more economical to use more expensive grease and reduce lubrication frequency.

That's why grease compounders and blenders are looking into every possible way to maintain and increase their profit levels.

High on investigation priority lists are the paste type concentrates. These concentrates contain solid lubricants. Molysulfide concentrates can be applied by grease guns or by brushing, and will stand up at temperatures as low as –100 F. and peaks as high as +500 F.

Concentrate users include a fast spreading number of industries. Major manufacturers in the automotive industry use paste type Molysulfide concentrates for pre-assembly lubrication of splines, cams, etc.

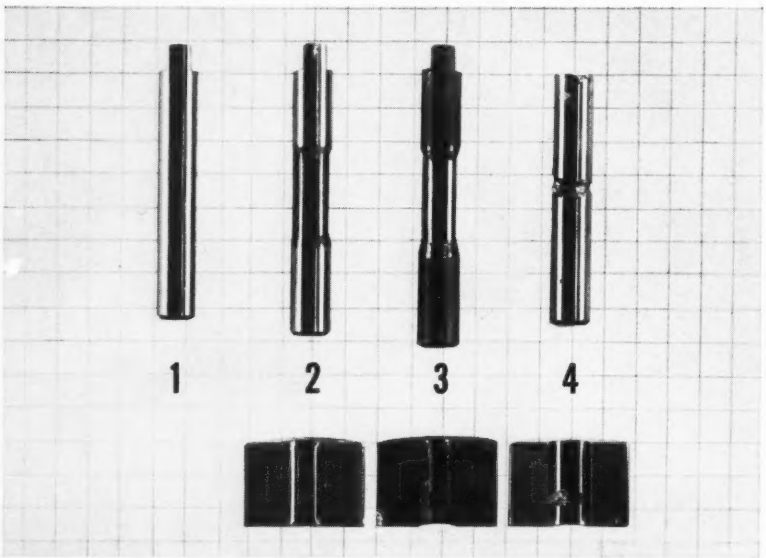
The aviation and missile industry is using an increasing amount to overcome low-temperature problems in servo-mechanisms, bearings and gears.

General industry is applying them, not only on metals exposed to continuous high temperatures, but also on plastic bearings, machine tool ways, press fittings and other moving parts where long lubricant life and high load carrying capacity is needed.

Much remains to be learned about the full potentialities of paste type concentrates but all signs indicate they are one of the answers to lubrication problems of the future.

When writing, refer to CL-110

From the German laboratory of Alpha Molykote Corporation comes new proof of Molysulfide's ability to resist galling and seizing at pressures beyond the yield point of most metals. Previous tests have shown that Molysulfide provides positive protection up to 475,000 psi. In this Alman Wieland test, similar to the Falex test, a ¼-inch pin actually extruded *without any surface damage* at pressures of 100,000 psi, while those using other lubricants were torn, galled or "frozen" to the point of breakage.



Photograph above shows mild steel test pins. No. 1: unused pin. No. 2 (lubricated .with mineral oil and Molysulfide) and No. 3 (with Molysulfide bonded coating) were subjected to rotating pressures between bearing halves. Both were elongated and extruded without galling, seizing, or weight loss. No. 4 shows typical failure with conventional lubricant. Note that the key sheared off and pin and block were galled and seized.

Extensive surveys among a great many independent laboratories indicate that the extrusion phenomenon produced with Molysulfide has never been achieved with any other conventional lubricant.

This proven load carrying ability of Molysulfide is only one of the reasons why grease compounders and lubrication engineers are investigating and testing new uses for MoS_2.

Other reasons include its extremely low coefficient of friction; its wide temperature range from –300 F to 750 F; its tenacious adherence to metal surfaces and a resultant great resistance to "scrape-off" and "wash-off"; and, its high chemical stability combined with long-life characteristics.

The uses for solid lubricants are multiplying. And—by test—Molysulfide is the superior solid lubricant.

When writing, refer to CL-111

Volume 17, No. 7
July, 1961

Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

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LETTERS TO THE EDITOR

Lubrication Engineering welcomes the comments and suggestions of readers with regard to articles published in its pages or concerning topics of interest to those engaged in any phase of lubrication engineering. Letters received cannot be acknowledged, but those felt to be of interest to other readers will be published. The society will not be responsible for the statements or opinions expressed.

More Meaningful Bench Testing

Sir,

There is general agreement that the familiar bench tests (Timken, Four Ball and Falex, used singly or in combination) can rarely be relied upon to predict the service performance of bearing materials and lubricants. Their value as research tools is, therefore, limited. The most one can expect from bench testing, as it is practiced in the wear and lubrication field today, is relative ratings under exaggerated conditions — ratings difficult to correlate with ratings obtained on different types of testing machines.

The situation is doubly discouraging for the serious worker in the field of boundary friction, wear and lubrication, where so many factors, variables and effects are still unknown or unexplained.

The only reliable means to date of predicting service performance where new designs, new materials and new techniques are involved, has been the testing of scale models or full-size mechanisms under actual service loads, speeds and environments. Such methods are expensive and time consuming. Worst of all, they contribute little to basic lubrication knowledge because the isolation and control of individual variables and influences is virtually impossible.

In order to be more meaningful—and useful—our bench tests must improve on two counts. *First*, they must more closely simulate the speeds and loads and temperatures of actual service. *Second*, they must keep more variables under more accurate control and measurement.

The history of accelerated service testing is full of examples of tests which lose significance by departing from environmental reality. The familiar salt spray tests for corrosion suffer from such an indictment. In early studies of fatigue life of metals much time was wasted by attempting to correlate destructive static tests with service life experience. Neither should we in lubrication expect highly accelerated *destructive short-time* tests of but a few minutes' duration to give reliable indications of life under more *moderately-stressed long-time* service. Marathon runners are not selected on weight lifting ability.

As for identifying, controlling and measuring more variables than we are accustomed to worry about, it is amazing how many new factors are being discovered to affect boundary friction and wear. Every year we are finding it necessary to control, measure and simulate new influences.

Nor is such a situation rare in the history of life testing. The large effect of residual surface stress on the fatigue life of structural components was first discovered when a mechanic making fatigue testing specimens used a chisel instead of a milling cutter to produce the notch. The chisel developed compression stresses in the bottom of the notch which greatly increased fatigue life.

In running 15 modified Timken bench testers almost continuously for three years during research on solid lubricants, it was observed that large variations in wear life were caused by slight variations in many factors such as: specimen cleaning methods, surface finish, rate of load application and ambient relative humidity.

As a recommendation, therefore, toward more meaningful bench testing wherever boundary friction is concerned, let it be urged:

First, to control, measure and more closely simulate real service values in: (a) mating material combinations, (b) surface hardness, (c) surface roughness, (d) direction of surface finish with respect to direction of sliding motion, (e) bearing pressure, (f) sliding velocity, (g) temperature in bearing contact area (ambient *plus* rise caused by friction), (h) ambient humidity, (i) surface deposits (oxides, contaminants, chemical conversion coatings), and (j) time and delay factors.

Second, to devise or modify bench testing apparatus to be much more precise from the following four standpoints:

1. Accuracy and maintenance of accuracy in loading. Verify by calibration. Suggested maximum deviation of ± 2%. (ASTM specifications for testing physical properties of materials require ± 1% loading accuracy.)

2. Uniformity of distribution of load over contact area. Most bench testers are highly deficient in this respect. Automatic maintenance of uniform load distribution over contact area should be mandatory.

3. Rigid maintenance of path of sliding motion. If specimens are permitted to wander, due to runout, play in specimen holders, or flexibility in the mounts, the area of real contact will change at random, affecting (1) and (2) above.

4. Accurate and continuous indication (or recording) of friction force. Smoothness of the friction force curve during testing is proof and demonstration of (1), (2) and (3) above — accurate loading, uniform loading, fixed path of sliding motion. If all three are under control and friction force fluctuations still occur, the test is revealing lubrication variables rather than machine variables. To suggest an accuracy of ± 5% in continuous friction force measurement would not seem to be undue, and would disclose many shortcomings of current bench test procedures.

Sincerely,
A. Sonntag, President
Alpha-Molykote Corp.

LUBRICATION IN THE NEWS

The Society will not be responsible for the accuracy of statements made in this column. Any reference to proprietary products does not imply an endorsement of such products by the Society.

FLUID AMPLIFIER HANDBOOK SERIES AVAILABLE

The technical results of a research program in fluid systems having no moving solid parts, conducted by the Army's Diamond Ordnance Fuze Laboratories in cooperation with universities, industrial firms, and other Government agencies, are being published as the *Fluid Amplifier Handbook*. Two chapters of the 20-chapter *Handbook* are now available to science and industry through the Office of Technical Services, Business and Defense Services Administration, U. S. Department of Commerce.

The chapters will be issued under four general section headings: *General Principles* (chapters 1 through 5); *Design of Components* (chapters 6 through 9); *Systems* (chapters 10 through 16); and *Production Test and Evaluation* (chapters 17 through 20).

The *Handbook's* introductory chapter points out that fluids in motion are currently used to perform a wide variety of tasks in military and industrial applications. For example, the proper operation of such devices as machine tools, steam engines, internal combustion engines, and rocket motors depends upon precise and timely control of moving fluids. The *Handbook* notes that application of theories of hydraulics, pneumatics, and thermodynamics, has resulted in the development of rugged and reliable systems, ranging all the way from windshield wipers and hydraulic brakes to rocket motors and giant hydroelectric generating stations.

The range of operating conditions for systems described in the *Handbook* includes: temperatures between minus 100 F and plus 7000 F; pressure drop across a single component of between 10^{-4} psi and 10^{4} psi; frequencies from zero to 100 kilocycles per second; and both one shot and continuous duty operation.

Order following chapters by number from OTS, U. S. Department of Commerce, Washington 25, D. C. PB 171 671-1 Chapter —Introduction —16 pages. 25 cents. PB 171 671-2 Chapter 7—Type (Boundary Layer) —6 pages. 25 cents. (Source: U. S. Department of Commerce, Washington, D. C.)

REFRACTORY MATERIAL FRICTION AND WEAR BEHAVIOR EVALUATED

An Air Force report now available from OTS on the wear mechanism of nonmetallic materials at high temperatures is:

Mechanism of Wear of Nonmetallic Materials. C. H. Riesz, Armour Research Foundation of Illinois Institute of Technology for Wright Air Development Division, U. S. Air Force. May 1960. 25 pages. Order PB 161 955 from OTS, U. S. Department of Commerce, Washington 25, D. C., 75 cents. The wear mechanism of nonmetallic materials at high temperatures was investigated. Single-crystal sapphire was examined in a friction apparatus made for studies up to 2200 C. A sapphire ball loaded at 22, 50, and 127 g was passed over a sapphire plate at 0.0053 cm/sec at 29-921 C. Both slider and plate were oriented so that the CO-axis was normal to the direction of traverse. With cleaned, as-received materials, coefficient of friction values were scattered. Prior heat treatment at 900-925 C. reduced scatter and gave peak values of 0.25-0.30 near 600 C. The wear areas on both ball and plate were 6 microns wide, and subsurface changes extended to 30 microns. Electron microscopy inspection suggested that extremely high surface temperatures occurred coincidentally with the friction process, but direct evidence of an adhesion mechanism was inconclusive. (Source: U. S. Department of Commerce, Washington, D. C.)

CONTINENTAL BEARING RESEARCH CORP. AWARDED GAS BEARING DEVELOPMENT CONTRACT

Continental Bearing Research Corp., New York, New York, was awarded a contract by Oak Ridge National Laboratory, operated by Union Carbide Corp.—for the U. S. Atomic Energy Commission, to design, build, and assemble a gas lubricated bearing system for testing a 12 HP high temperature motor, running at 24,000 rpm. The unit is designed to operate in helium at 400 psia and 800 F. The bearings are helium-lubricated and make use of the helium gas as the bearing lubricant.

In this application a system results whereby no rotating seals are required to separate bearing lubricants from process fluids. Lubricant contamination problems are eliminated and a completely sealed system is obtained resulting in near zero gas leakage. Since all relatively moving parts of the gas bearings are completely separated by a gas film, no wear takes place during normal operation and reliability due to infinitely long bearing life is increased. In general, gas-lubricated bearings appear to offer a solution to many current problems in the field of high temperature and high-speed uncontaminated operation.

Continental Bearing Research Corp. is primarily engaged in the research design, and manufacture of fluid-film bearings; both liquid and gas-lubricated. (Source: Continental Bearing Research Corp.)

1960 SURVEY SHOWS NEW PRODUCTION HIGH FOR LUBRICANTS

Over one billion pounds of lubricants were produced in the United States during 1960, and a gain was noted over 1959, it was reported by the National Lubricating Grease Institute.

The totals for both countries represented the highest production in the four years the survey has been taken, in spite of the fact that lubricating greases for industrial purposes, such as for steel mills, were down sharply last year. Gross production in the U. S. was over one billion pounds, while Canadian poundage exceeded 76 million. The survey further indicated certain trends with regards to the various soaps used in the manufacture of greases. (Source: National Lubricating Grease Institute)

(*Continued on page* 312)

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LUBE IN THE NEWS

(*Continued from page* 310)

REPORT ON LUBRICANT ANTI-SCUFFING PROPERTIES AVAILABLE

Two Air Force Research reports on the anti-scuffing properties of lubricants and petroleum base hydraulic fluids have been released to science and industry through the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. The two reports are described below:

Load Support and Anti-Scuffing Properties of Lubricant—Part 2—WADC Universal Gear and Spline Lubricant Tester. L. R. Drane, Jr., 2nd Lt., USAF, Materials Central, Wright Air Development Division, U.S. Air Force. May 1960. 16 pages. Order PB 171 055 from OTS, U.S. Department of Commerce, Washington 25, D.C., 75 cents. The design and operating characteristics of a gear and spline lubricant tester are described. The results of studies to determine the effect of lubricant flow rate, gear speed, and inert atmosphere on gear scuff load are presented. Lubricant load carrying ability decreased sharply in the 5000 to 20,000 rpm range. A slight increase in scuff load with increasing speed was noted in some cases. The use of an inert atmosphere caused a decrease in scuff load rating with a mineral oil, a sebacate, and a silicone-ester blend. Two silicone fluids showed no significant change in scuff load when tested in an inert atmosphere.

Performance of Petroleum Based Hydraulic Fluids in a Pump Loop at 3000 PSI and 275 F. R. N. Johnson, 1st Lt., USAF, Materials Central, Wright Air Development Division, U.S. Air Force. June 1960. 80 pages. Order PB 171 063 from OTS, U.S. Department of Commerce, Washington 25, D.C., $2.25. Fluid breakdown and pump wear were investigated in a pump loop at 275°F and 3000 psi on five petroleum based hydraulic fluids. The mechanical shearing of the fluids resulted in excessive loss of viscosity, although their resistance to oxidation was not appreciably changed. The wide variations in the wear data of these fluids indicated their difference in lubrication characteristics in the particular system employed. Bench wear data did not correlate with the pump wear results. (Source: U.S. Department of Commerce, Washington, D.C.)

INDUSTRY NOTES

The formation of Wallace Filters, Inc., Lebanon, Indiana, was announced recently. The new firm will design, manufacture, develop, distribute and sell all types of industrial filters. Wallace Filters employ the depth principle using Fullers Earth.

Complete facilities for applying bonded solid film lubricant coatings to metal and plastic parts are being offered by the Wacho Mfg. Co., Milwaukee, Wisc. as a result of a licensing agreement recently concluded between the company and The Alpha-Molykote Corp., Stamford, Conn., producer of molybdenum disulfide lubricants. Under the terms of the agreement, Wacho will provide technical assistance and application facilities to manufacturers wishing to prelubricate parts with dry Molykote resin bonded coatings.

Dr. David B. Pall, president of Pall Corporation, Glen Cove, New York, has announced its merger with Trinity Equipment Corporation, Cortland, New York.

Trinity, a producer of dry air and gas systems, thermowells and thermocouples will continue as a wholly owned subsidiary of Pall Corporation.

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ROLLING CONTACT BEARINGS—Studies at extreme temperatures and speeds; materials, methods of lubrication, endurance life. Instrument bearings.

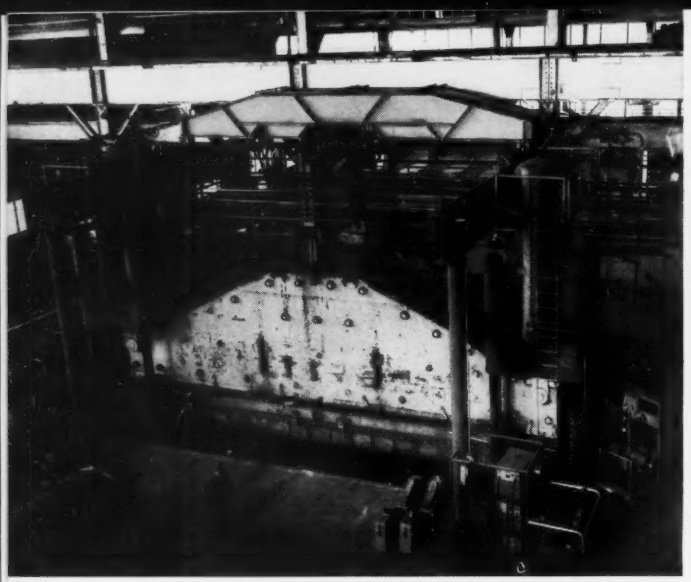
PROPERTIES OF LUBRICANTS—Greases, gases, liquids, solids. Thermal and atmospheric influences.

CHEMISTRY OF SURFACE FILMS—Interaction of lubricated metal, lubricant and environment and their contribution to lubrication processes. Special research techniques.

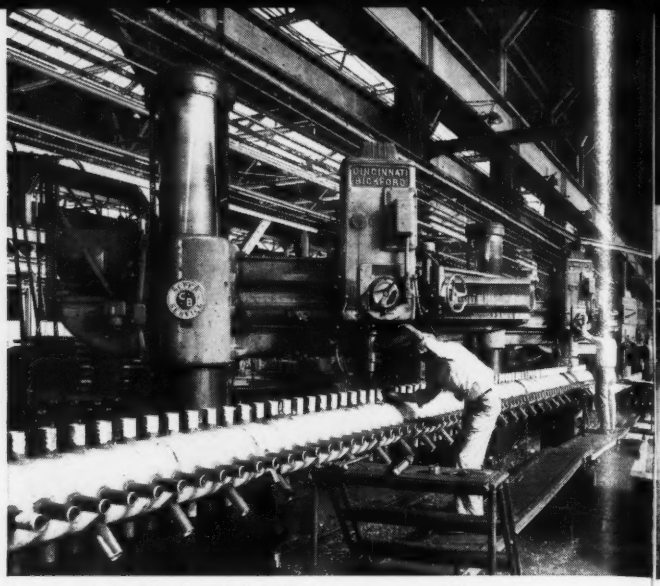
FRICTION AND WEAR—Studies to clarify lubrication processes and properties of materials in sliding contact.

GEARS—LIQUID FILM BEARINGS—METAL PROCESSING—NUCLEAR SYSTEMS.

A detailed program will be available in August.

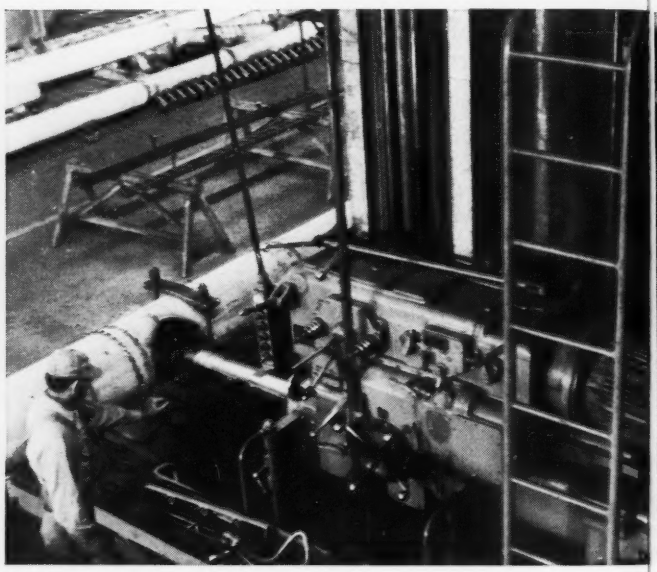


Overhead view of 2500-ton press. It forms heavy steel plate for drum shells—up to 7 inches thick, up to 30 feet long. Gulf Harmony 61 is used in the hydraulic system.



Cincinnati Bickford radial drill presses — working on headers. Gulf Harmony 61 is used in column mechanism, drill-head mechanism and main drive gear boxes. Gulf Precision Grease is applied to fittings.

Colburn Vertical Boring Mill—milling a drum head. Gulf Harmony 61 is used in the circulating system for main drive gears; in the reservoir for feed change gears.



Giddings & Lewis 6" horizontal boring machine—boring hole in header. Gulf Harmony lubricates the column slides and screws on this new machine.

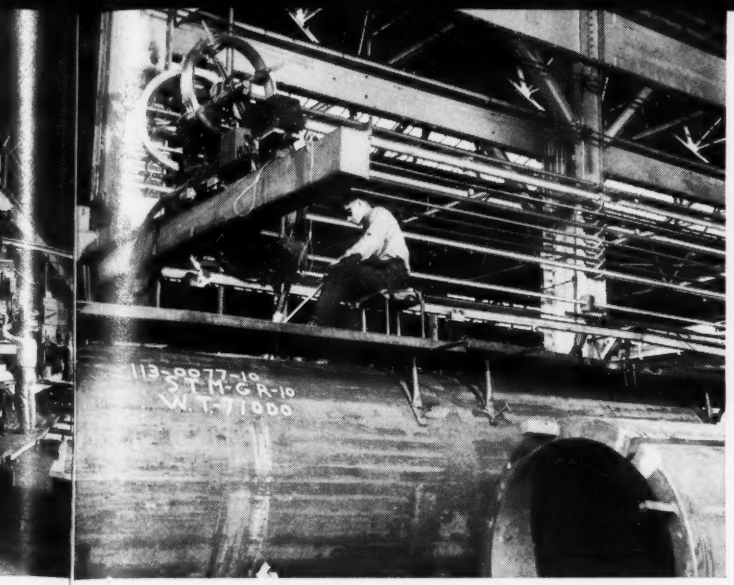
Simplified lube program helps Babcock 16 lubricants to just 7...

The Paris, Texas, plant of Babcock & Wilcox specializes in the manufacture of steam generating equipment. Typical examples: 65-ton boiler drums and 4-ton tube sections.

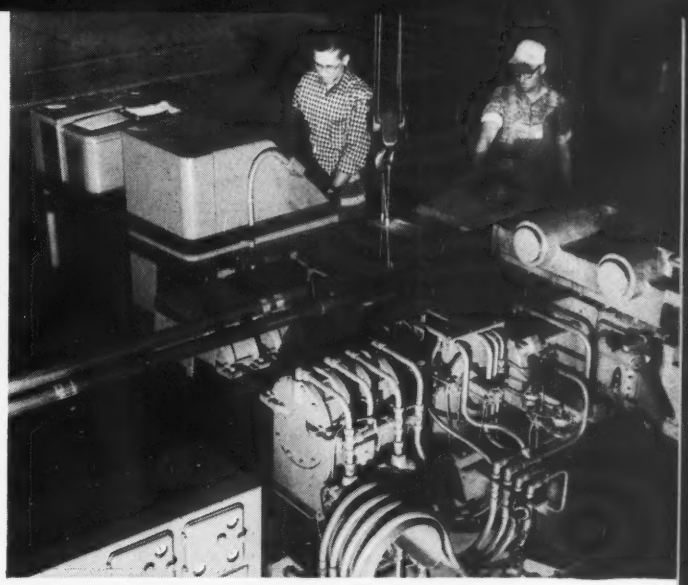
Recently, Gulf Sales Engineers conducted a lubricant survey in this plant. As a result, lubes were reduced from 16 to 7. This reduced the possibility of application errors and simplified ordering, bookkeeping and handling.

"It's important to keep lube recommendations up to date," says C. C. Eagon, Master Mechanic. "We call in lubrication engineers as new machines arrive. And they help us translate the manufacturer's lube recommendations in terms of their oils and greases."

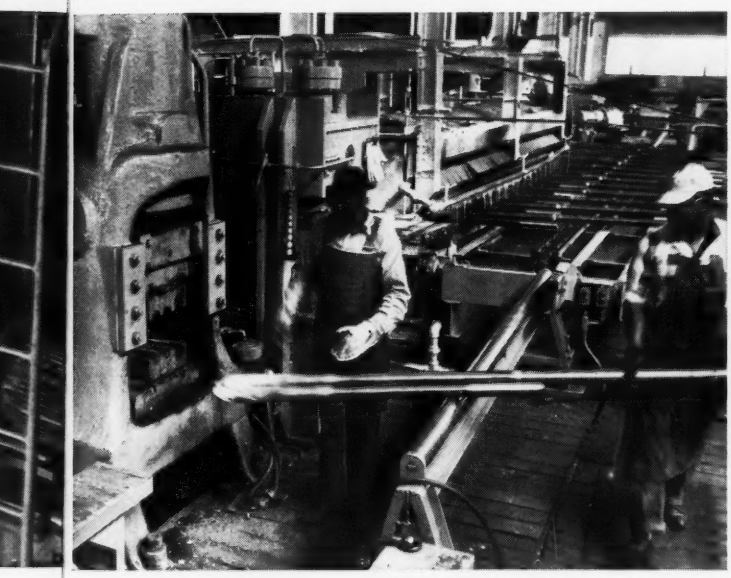
The seven recommended grades are really four basic types of Gulf oils and greases. First, Gulf Harmony® oils—highly stable lubricating oils with excellent water separating properties; inhibited against



Automatic submerged arc welder is used to weld drum halves together, Gulf Precision Grease and Gulf E.P. Lubricant 95 protect bearings and gears of this machine against excessive wear.



Tubes joined together in butt-welder. The hydraulic system reservoir is filled with Gulf Harmony 44. Gulf Harmony 61 is used in milling machine gear box. Gulf Precision Grease lubricates guide shaft bearings.



Sizing press. Turbine is sized in this press after it goes through swedging, upsetting and bending operations. Ways and shaft bearings are lubricated with Gulf Precision Grease, from central greasing system.

Works Manager R. L. Reed (left) talks with Frank P. Mauro, Gulf Sales Engineer. The drums behind them are being shipped to a new power plant in Santos, Brazil.

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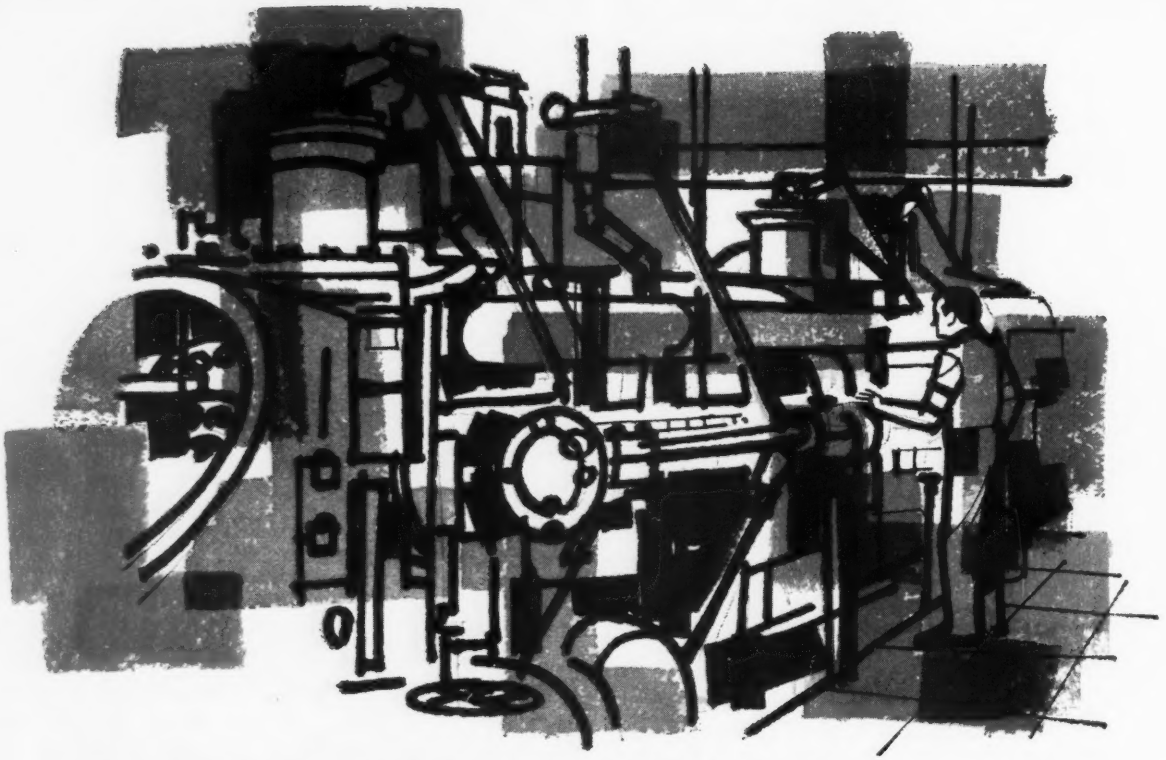

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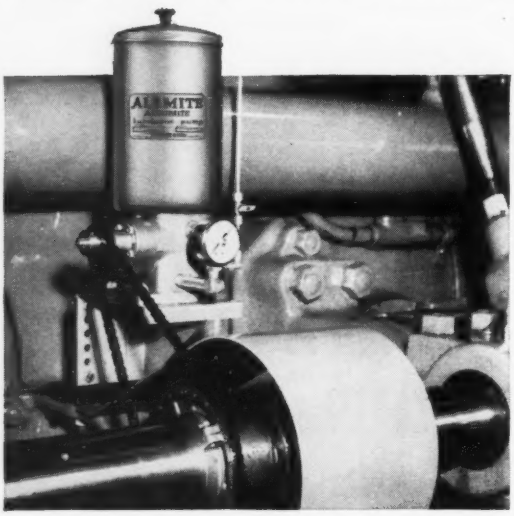

Close-up of the Alemite Mechanical Pump and Timer driven by timing shaft by means of a chain and sprocket.

By utilizing a chain and sprocket to transfer rotary motion to an Alemite Mechanical Pump and Timer you can supply efficient, automatic Accumite Centralized Lubrication to as many as 400 points or bearings. That's over 30 times the capacity of other pumps! The Alemite Pump eliminates the "rat's nest" of lines other systems require—serves all bearings with a single line. Shots are measured at the bearing, *not at the pump*. Line length is no factor and any size shot from .00055 oz. to .012 oz. or more can be delivered to any point. Two more Alemite advantages are the big capacity 5-pint reservoir and an alarm system assuring accurate, positive lubrication.

The Alemite Pump and Timer is completely mechanical, uses no air or electricity. Cam operated valve closes at intervals determined by the pump input shaft speed to deliver positive, measured amounts of lubricant to each point in the system. Measurement is by piston stroke, wear not a factor, pressures remain constant and can be read on any type gauge.

Contact your local Alemite distributor or write for free illustrated literature on the Alemite Mechanical Pump and Timer and the Accumite Centralized Lubrication System.

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SOCIETY NEWS

NEW ASLE MEMBERS

MAY, 1961

CHICAGO

H. Ted Dinkelkamp
Alemite Div., Stewart Warner Corp.
Chicago, Illinois

Richard B. Rydin
American Oil Company
Chicago, Illinois

CLEVELAND

Donald P. Gleichauf
The Standard Oil Co.
Akron, Ohio

John D. Hetcher (R)
Werner G. Smith, Inc.

PITTSBURGH

Richard A. Smucker
Gulf Oil Corporation
Pittsburgh, Pennsylvania

LOS ANGELES

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Union Oil Co. of Calif.
Brea, California

Gaylord E. Hold
Wynn Oil Company
Azusa, California

Gordon Walker (R)
Douglas Aircraft Co.
Santa Monica, California

NEW YORK

Charles P. Covino
General Magnaplate Corp.
Belleville, New Jersey

Harry W. Morey Jr. (R)
Celanese Chemical Company
New York, New York

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James David Conboy
Aeronautical Engine Lab.
Philadelphia, Pennsylvania

Samuel A. Cummins
Lanco Engineering Sales Co.
Philadelphia, Pennsylvania

Robert M. Fitch
Atlantic Refining Company
Philadelphia, Pennsylvania

Ernest L. Florence
Acheson Dispersed Pigments Co.
Philadelphia, Pennsylvania

W. Ronald Benoliel
Quaker Chemical Products Corp.
Conshohocken, Pennsylvania

Henry Y. Toland
Alemite Co. of Eastern Pa.
Philadelphia, Pennsylvania

Frank G. Woodson
Westinghouse Electric Corp.
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Wyandotte, Michigan

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Olsen Mfg. Company, Inc.
Royal Oak, Michigan

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Virgil C. Hutton (R)
Dayton, Ohio

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E. F. Houghton & Co.
Baltimore, Maryland

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New Bedford, Massachusetts

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Red Wing Oil Company
Portland, Connecticut

James E. Malloy
Mobil Oil Company
New Haven, Connecticut

Ward B. Wahl
Mobil Oil Company
Clinton, Connecticut

WHEELING

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Wheeling Steel Corporation
Wheeling, West Virginia

RICHMOND

Ward W. Johnson
Esso Standard
Richmond, Virginia

OKLAHOMA

E. R. Cartmill
Phillips Petroleum
Tulsa, Oklahoma

Lonnie Jones
Phillips Petroleum
Tulsa, Oklahoma

W. R. Mallory
Royal Manufacturing Co., Inc.
Tulsa, Oklahoma

G. C. Williams
Phillips Petroleum
Oklahoma City, Oklahoma

UNAFFILIATED

Hugh M. Chesley
Nova Scotia Pulp Ltd.
Nova Scotia, Canada

B. M. Kays
Cities Service Oil Co.
Cedar Rapids, Iowa

Charles T. Moorman
Texas Research Associates
Austin, Texas

FOREIGN

Joseph Pitloun
J. Pitloun
Buenos Aires, S. A.

*Reinstated

PERSONALS

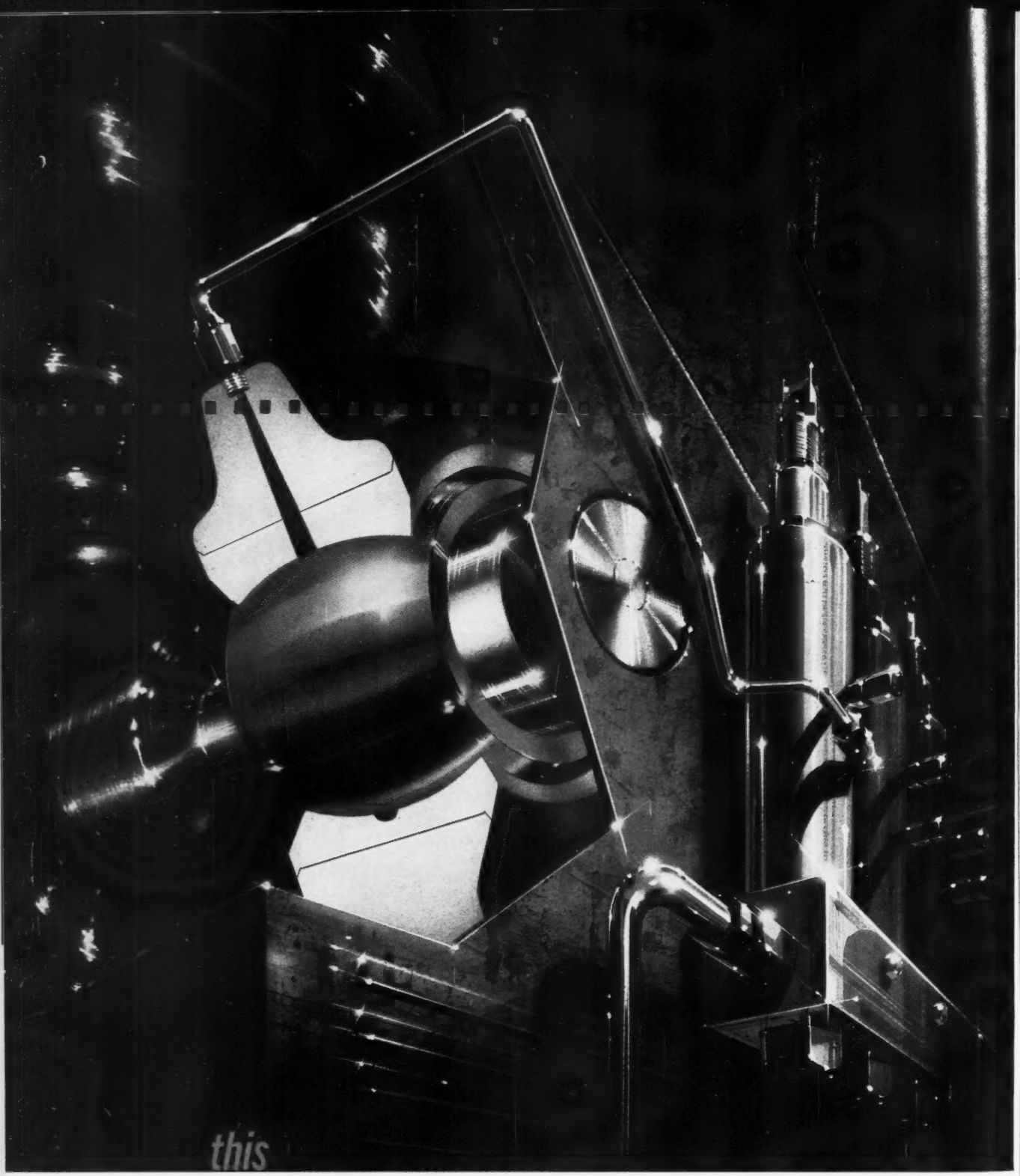
With a recent series of management promotions for Lincoln Engineering Company of St. Louis, a division of McNeil Machine and Engineering Company of Akron, Ohio, came the announcement that **Carl Mueller**, formerly Director of Engineering, has been appointed General Manager. Mueller joined Lincoln in 1930 and managed Product Development and Market Research activities prior to 1952 when he became Director of Engineering.

CARL MUELLER

Aluminum Company of America today announced the appointment of **D. B. Wood** as manager of bearings development as part of a move to expand the company's sales development division along industry lines.

Mr. Wood, who has been with Alcoa for 27 years, will be responsible for furthering the use of aluminum in the area of railroad journal bearings, industrial equipment, automotive, and heavy duty engine bearings and bushings.

Vice-President **Joseph D. Hartnett**, Marketing, has announced appointment of John L. Bates, Jr., as general manager of Canfield Oil Company, a Sohio subsidiary.



bearing gets 0.003 cubic inches of lubricant every 15 minutes . . . automatically. installation cost: $5.75 per bearing.

the frequency concept

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KEY TO:

lower maintenance costs / longer parts life

The frequent application of small, measured amounts of refinery-pure lubricant directly to bearings . . . that's the reason why automatic lubrication gives such remarkable savings in maintenance costs and such dramatic increases in parts life. The timeclock becomes the overseer of this precise operation. It triggers the charge of lubricant through main supply lines to the injectors that meter the exact amount to the individual bearings.

The highly polished bearing surface is always protected by a fresh supply of lubricant. It's little wonder that these precision parts stand up under constant high-speed service with a fraction of the wear shown by hand-lubricated bearings. The expensive result of improper lubrication comes with parts replacement. It isn't just the cost of the bearing . . . it's the labor time to replace it and the lost production!

Whether you build or buy machinery, you protect your investment with a dependable Lincoln automatic lubrication system.

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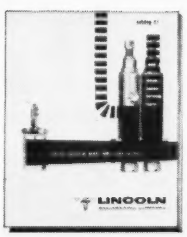

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☐ Please send me your new Catalog 82 on Lincoln centralized lubrication systems.

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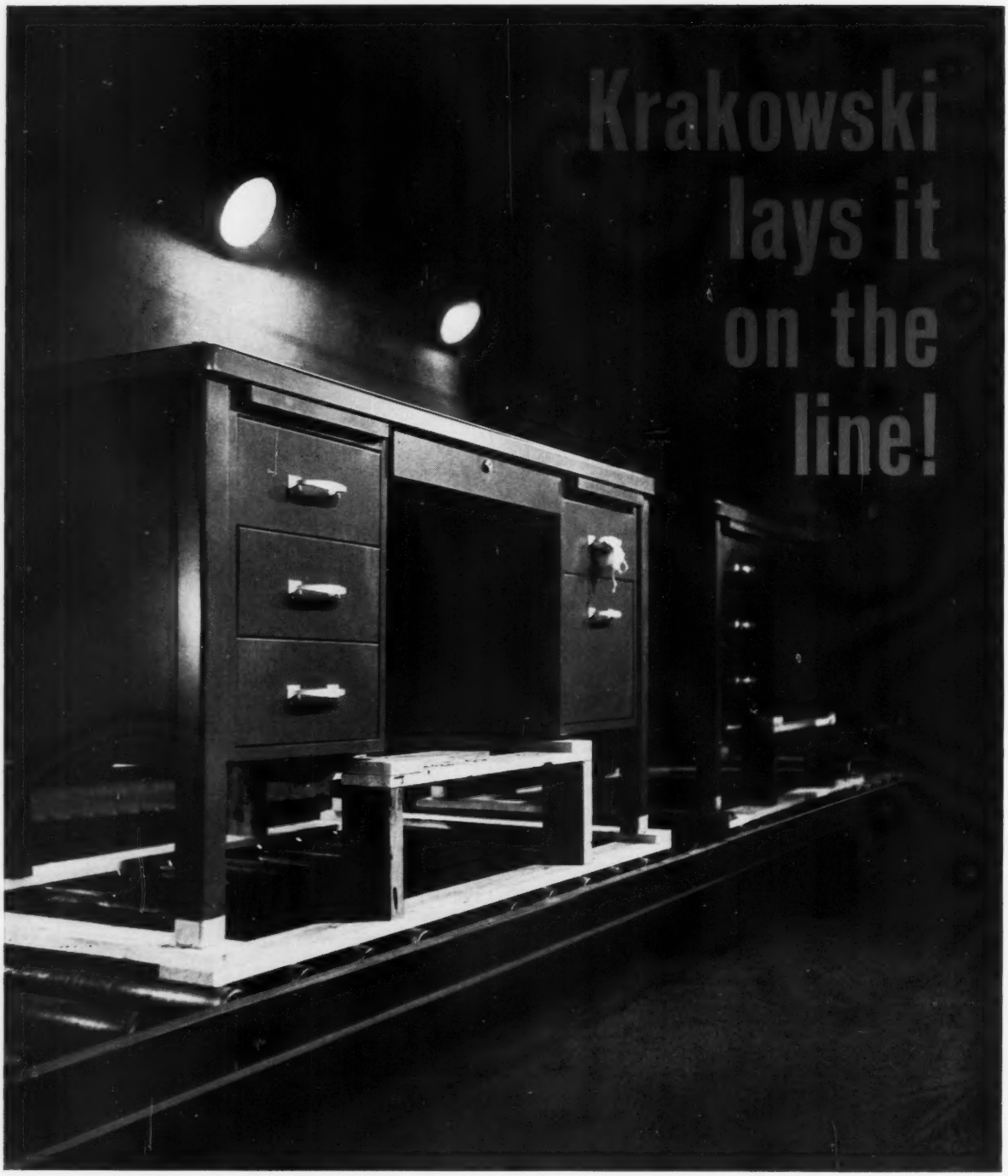

Lou Krakowski, General Superintendent of the Harrison Sheet Steel Company, is a guy who makes no bones about what he wants. It's service! And, for twenty years, he has been getting what he considers the best . . . Cities Service.

Turning out, among many other things, 125 steel desks a day, he wants complete and dependable lubrication service. One of the many Cities Service products he uses to get this job done is Trojan H-2 grease. For general greasing on all equipment, multi-purpose Trojan H grease has a wide range of application. And, because of the variety of jobs Trojan H grease does, it reduces his necessary lubrication stocks.

If you have to *get it on the line* . . . call your nearest Cities Service office . . . or write Cities Service Oil Company, 60 Wall Street, New York 5, N. Y.

CITIES SERVICE
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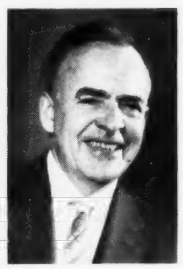
SECTION NEWS

FATHER AN SON SERVES HAMILTON SECTION

Robert G. Forsythe was installed as Chairman of the Hamilton Section for the 1961-62 season at the May meeting. Bob follows his father, Robert E. Forsythe (Assistant Chief Lubrication Engineer with The Steel Company of Canada, Ltd.) who served as Chairman of the Hamilton Section 2 years ago.

R. G. FORSYTHE



R. E. FORSYTHE

With his father's extensive work in the field of design and installation of circulating and centralized lubrication systems, along with vital support to local and national ASLE activities, and writing articles on Lubrication Engineering, Bob was raised in the lubrication business. He began work at the age of 16 years in the grease plant founded by his grandfather. Later, he worked in quality control, research, and sales; subsequently, he was elected to the post of Vice-President and Director in 1957 of The Ontario Lubricating Co., Ltd. Also, he is presently associated with Moly-Film of Canada.

Bob began attending ASLE meetings with his father while a student, and eventually served as Director, Treasurer, Program Chairman, Vice-Chairman, and now, Chairman of the Hamilton Section.

As far as can be discovered, this is one of the few father and son membership combinations in ASLE, and further, this is probably the first time in the Society's history that both father and son have been chairman of a local section.

Rochester—The final Executive Committee Meeting of the season discussed the following items to increase membership and attendance at Section Meetings: (1) Publicity must reach management to get the boss to say "go". Letter describing ASLE and "What's in it for me—company and man" for local industry with a telephone follow-up. (2) Preparation of list of men who should be members with concentration on enlisting potential members. (3) Set up telephone committee to contact members 3-5 days prior to meeting as reminder.

Baltimore—The Officers and Executive Committee Members for the 1961-62 season are as follows: Section Chairman—Robert B. McNatt, Garlock, Inc.; Vice Chairman — Henry K. Warth, Esso Standard Oil Co.; Secretary — Thomas A. Bessent, Bethlehem Steel Co.; Treasurer—R. L. Mohlhenrich, Louis H. Hein Co. Executive Committee Members: Henry B. Shortley, Western Electric Co.; Robert L. Gordon, Dryden Oil Co.; George J. Morris, The Martin Co. Advisory Council: Howard D. Plumly, National Refining Co.; Harry A. Raw, Jr., Shell Oil Co.; C. J. "Dutch" DeVries, Sexton & Peake, Inc.

Twin Cities—The newly elected officers of the Twin Cities Section for the 1961-62 season are as follows: Ralph G. Olson, Sinclair Refining, Minneapolis, Minn., Chairman; Joseph P. Pardo, Sta-Vis Oil Co., St. Paul, Minn., Vice Chairman: William F. Cashin, Minneapolis-Honeywell Regulator Co., Minneapolis, Minn., Secretary; Milton K. Giese, Farmhand Div. of Daffin Corp., Hopkins, Minn., Treasurer.

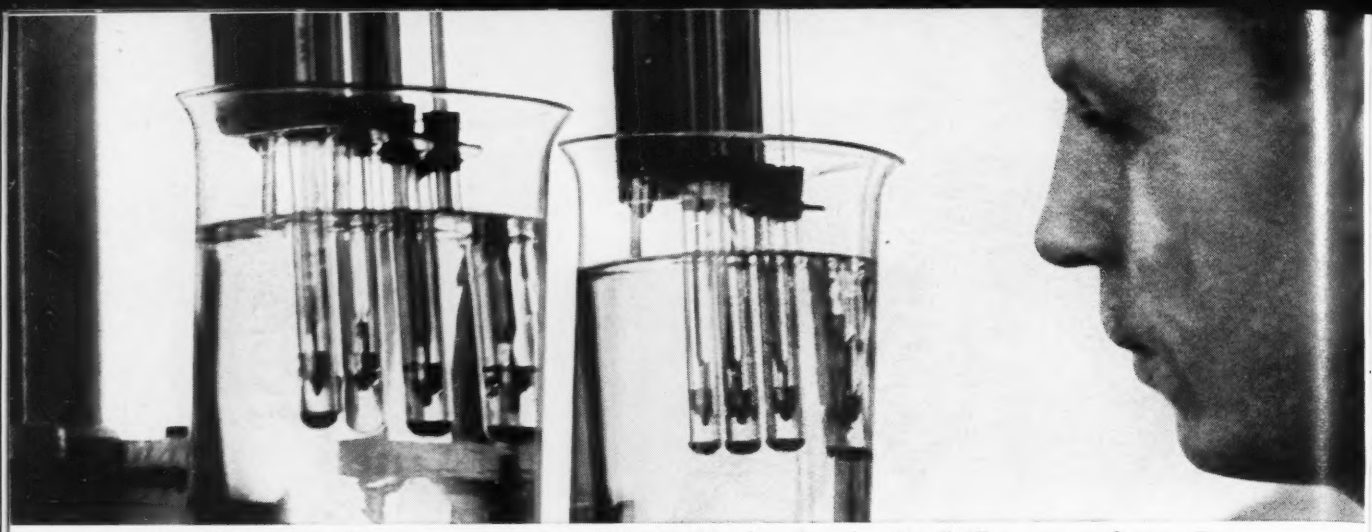
IN MEMORIAM

The many friends of Mr. Carl O. Graves regret to hear of his death on May 21, 1961.

Carl was a member of long standing of the Cincinnati Section, as well as one of its most loyal and devoted members. His passing was sudden and peaceful while on a vacation trip in Michigan.

He had just recently retired from the Cincinnati Milling Machine Co., after more than 32 years of service in the firm's research activities. The major portion of this time was devoted to research in the areas of friction, lubrication, and wear.

The photographs above show personalities at a recent New York Section meeting. Left photo: R. Rinschler, Treasurer, and R. L. Moy, Greeting Committee Chairman, are seen awaiting members and guests. Right photo: Section Chairman S. E. Manilych is shown greeting guest speaker E. J. Parker.



Dropping point test shows how greases react to heat. Beaker fluid has been heated to 390°F. All greases tested except Darina (second tube from let) have passed from solid to liquid state.

BULLETIN:

Shell reveals the remarkable new component in Darina Grease that helps it save up to 35% on grease and labor costs

Darina® Grease is made with Microgel*, the new thickening agent developed by Shell Research.

Darina lubricates effectively at temperatures 100° hotter than most conventional soap base greases can withstand.

Read how this new multi-purpose industrial grease can help solve your lubricating problems and even save you up to 35% on grease and labor costs.

THERE IS no soap in Darina Grease. No soap to melt away—wash away—or dissolve away.

Instead of soap, Darina uses Microgel—a grease component developed by Shell Research.

What Microgel does

Because of Microgel, Darina has no melting point. It won't run out of gears or bearings.

Compared with most conventional soap-base greases, Darina provides significantly greater protection under adverse service conditions.

Mix water into Darina and the grease does not soften. It shrugs off water—won't emulsify.

Resists heat

Darina will withstand operating temperatures 100° hotter than most conventional multi-purpose greases. It cuts leakage and reduces the need for special high-temperature greases.

Also, Darina resists slumping, thus forming a more effective seal against foreign matter.

Saves money

Shell Darina can reduce maintenance expenses while it protects your machinery. Savings of up to 35% on grease and labor are quite possible.

In some cases lubrication intervals have been extended to double what they were before. Less grease is consumed and less time consumed applying it.

For details, see your Shell Representative. Or write: Shell Oil Company, 50 West 50th Street, New York 20, New York.

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SHELL

A BULLETIN FROM SHELL
—where 1,997 scientists are helping to provide better products for industry

Vol. 17, No. 7

Lubrication Engineering

the faster pace

The pace of business grows faster all the time. ASLE methods of operation must continue to improve to keep up with this faster pace.

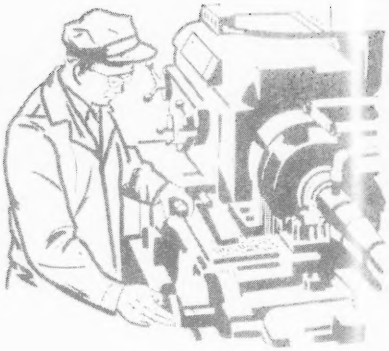
One big step forward is the application of the newest data processing techniques to the maintenance of ASLE membership records. This month, each local section will receive a roster of their members. In September, a full roster of all ASLE members will appear in this magazine. Each of these lists will be produced in full without error by an amazing machine in less than an hour.

This change in methods will provide the ASLE staff with more time to spend meeting the individual needs of members. It should also substantially reduce those annoying mechanical errors that crop up when a repetitive clerical operation is performed by hand.

The organizational side of ASLE faces a great challenge in keeping pace with the quality and service of the technical and educational side of ASLE. Please help us do this job right.

Donald B. Sanberg
Executive Secretary, ASLE

Two quantities of major importance that are influenced by use of a cutting fluid are *surface finish* and *tool life*. Surface finish is most critical at low cutting speeds while tool life is primarily of interest at higher cutting speeds. The shape of the crater that develops on the tool face plays a major role in determining the rate of tool wear and a cutting fluid can alter this crater shape in such a way as to either increase or decrease tool life. The cutting fluid tends to control the size and stability of the built-up edge at low cutting speeds. Three screening tests of value are the four ball wear test, a tapping test, and a low speed orthogonal cutting test. The four ball test serves to screen cutting fluid additives with regard to their wear performance, while the tapping tests and orthogonal cutting are useful in evaluating the finish and force improving characteristics of a fluid. Representative data of all of the aforementioned types are presented in this paper and discussed relative to cutting fluid performance.



by I-M. Feng,
Esso Research and Development
Linden, New Jersey

A. Gujral,
Research Assistant,
Massachusetts Institute of Technology,
Cambridge, Massachusetts.

M. G. Shaw,
Professor of Mechanical Engineering,
Massachusetts Institute of Technology,
Cambridge, Massachusetts.

Cutting Fluid Performance

INTRODUCTION

In screening potential cutting fluid additives in the laboratory it is of interest to consider a variety of characteristics such as the following:

1. basic wear properties;
2. ability to produce good surface finish and low forces at relatively low cutting speeds;
3. ability to give improved tool life at relatively high cutting speeds;
4. corrosive properties;
5. toxicity;
6. cost.

In selecting an effective cutting fluid additive two performance criteria stand out above all others. These are the improvement of surface finish and the extension of tool life. Since good surface finish is most difficult to obtain at cutting speeds below about 200 fpm, due to built-up edge formation in this speed range, tools that normally operate at relatively low speeds should be used to evaluate surface finish. Tool life, on the other hand, is of interest for tools that operate at all speeds, and in particular for tools that operate at high cutting speeds (and therefore at high temperatures), where tool life is relatively short at best.

Presented at the 15th ASLE Annual Meeting, Cincinnati, Ohio, April, 1960.

FOUR BALL WEAR TEST

The four ball wear test is a useful one in evaluating basic wear characteristics (item 1 above). In this test the upper ball slides on the lower three at constant velocity, and after a given time the diameter of the wear scar is measured. The points of contact are immersed in the test oil throughout the test. Steel balls of 440 stainless steel were used under the following test conditions:

Load	60 kg
Speed	1800 rpm
Test duration	1 min.
Temperature	ambient

The additive is tested at a concentration of 1% by weight in mineral oil.

The data of Table 1 illustrate the nature of the results obtained in the four ball test. The chip length ratio referred to in Table 1 is the ratio of the deformed to the undeformed chip length. The additives are a series of phosphorus compounds, and the following observations may be made; based on the wear scar results:

1. Phosphites are superior to their corresponding phosphates. Tri-*n*-butyl phosphite (test 9) gave a much smaller wear scar than tri-*n*-butyl phosphate (test 7).

2. The thiophosphates in general are somewhat better than their corresponding

non-thio analogues (test 7 and 8). However, the improvement in performance resulting from the presence of sulfur in the structure is not impressive.

3. Chlorination of the alkyl groups in the phosphites is very helpful in improving the four-ball performance (tests 4 and 10).

TABLE 1.—Four-Ball Wear Evaluation of Phosphorus Compounds and Correlation with Chip-Length Data

TEST NO.	ADDITIVE	WEAR SCAR DIA., MM[1]	CHIP-LENGTH RATIO[2]
1	None	Weld	.37
2	$(C_6H_5O)_3P$	4.7	.48
3	$(C_4H_9O)_3PS$	4.5	.48
4	$(C_4H_9O)_3P$	4.3	.48
5	$(C_4H_7O)_3PS$	4.2	.48
6	$(C_4H_9O)_2(C_4H_9S)PO$	3.9	.49
7	$(C_4H_9O)_3PO$	3.6	.44
8	$(C_4H_9S)_3PO$	2.9	.48
9	$(C_4H_9O)_3P$	0.4	.48
10	$(ClCH_2CH_2O)_3P$	0.4	.50
11	$[ClCH_2CH(CH_3)O]_3P$	0.4	.50
12	A, (Treated $[ClCH_2CH(CH_3)O]_3P$)	0.4	—
13	B, (Treated $[ClCH_2CH(CH_3)O]_3PS$)	0.4	—
14	Carbon tetrachloride	2.5	—

[1]For 1% concentration by weight in mineral oil and stainless steel specimens.

[2]For 10% concentration by weight in mineral oil and A.I.S.I. 1018 steel specimens.

CHIP LENGTH RATIO TESTS

Sulfur in the thiophosphates has a much smaller effect in reducing the wear scar in the four ball test with stainless steel balls than it does in improving the chip length performance in machining a low-carbon steel.

Additives A* and B** are complex phosphorus compounds that are seen to give outstanding results in the four ball test. A one percent concentration of carbon tetrachloride is relatively ineffective in this wear test.

These observations are in fair agreement with the conclusions reached in previous studies of phosphorus compounds using the less sensitive chip length ratio technique (1, 2) in which the ratio of chip length to work length was determined in a simple two dimensional cutting operation. These chip length ratio tests were performed with a 18-4-1 high speed steel tool (rake angle 15°; clearance angle 5°). The work material was AISI 1018 steel. The length of the specimen in the direction of the cut was two inches and its width measured along the cutting edge was 0.25 inch. A constant depth of cut of 0.015 inch and a cutting speed of 12.25 inches per minute were used in all tests. The chip length ratio data are included in Table 1 and are seen to be less sensitive to the chemical structure than the four ball wear results.

*Additive A is treated tris(2-chloro-1-methylethyl) phosphite

**Additive B is treated tris(2-chloro-1-methylethyl phosphorothionate

CUTTING FORCES AND SURFACE FINISH

A simple screening test that provides basic surface finish and force information concerning cutting fluid additives is one in which a two dimensional chip is produced at slow speed and under controlled conditions. The test arrangement is as indicated in Fig. 1. Here the workpiece is shown clamped in a dynamometer capable of recording the horizontal (F_p) and vertical (F_Q) components of the cutting force. The workpiece and dynamometer are attached to the table of a milling machine, while the stationary tool is clamped to the overarm of the machine. The workpiece is generally ¼ inch wide and about 1½ inches long. A depth of cut of 0.005 inch is a convenient value and may be set on the machine by adjusting the table upward relative to the tool. Successive cuts are taken using a given fluid until the forces reach equilibrium and the depth of the layer removed is checked by use of the dial indicator. At the end of a test the arithmetic average surface roughness (h, μ in.) is measured using a tracer instrument. The chip length ratio (r) and the initial radius of curvature of the chip (ρ, in) are also recorded.

A low carbon steel that has not been resulfurized is a more sensitive material against which to check cutting fluid additives than is the same steel resulfurized. Representative results are presented in Table 2 for a tool having a rake angle of 10° and clearance angle of 5°, when cutting at a speed of 1 ipm.

The variable of most importance in these tests is surface roughness (h). The reason for studying the other quantities is

1. To provide a better insight into what the fluid is doing.
2. To see if another more easily measured variable, such as cutting force, might be used to provide a more sensitive and reproducible measure of surface finish.

In the past considerable emphasis has been placed on cutting force F_p and chip curl in studying cutting fluid performance at low speeds. However, the data

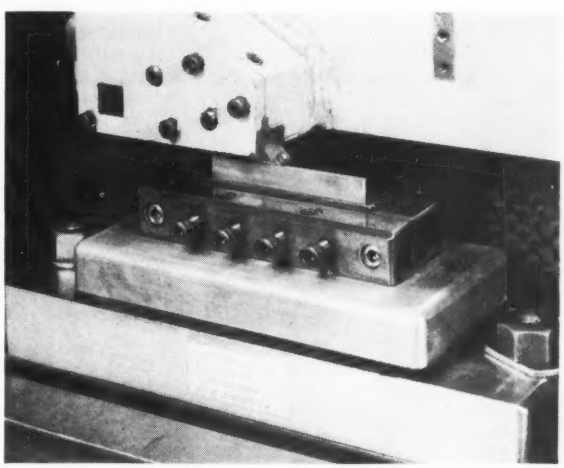


Fig. 1. Apparatus used for low speed cutting studies, showing tool, work and two component dynamometer.

presented here show that cutting force is not a reliable measure of finish. For example, trichloroethane and carbon tetrachloride are seen to yield the same finish while the cutting forces and chip curl produced by these two fluids are significantly different. Other instances showing a lack of correlation between finish and forces and chip curvature are evident in the data of Table 2. The important conclusion to be derived from these observations is that there is no other measurement which will correlate with surface finish.

While water and water-base cutting fluids give good finish at the low speed of 1 ipm, the finish obtained with these fluids falls off rapidly as the cutting speed is increased to a few feet per minute. Carbon tetrachloride will also cease to be effective at a few feet per minute but trichloroethane continues to give good finish to quite high speeds (100 fpm). While trichloroethane is not as toxic as carbon tetrachloride, it is still too dangerous to be used in the workshop. Oils "6" to "8" also continue to give good finish to higher speeds and are non toxic. Of the three oils "6", "7", "8", which give about equal finish and force results, the first two are black and disagreeable due to their high sulfur content, whereas the third (oil "8") is light in color. Due to their high active sulfur content oils "6" and "7" will badly discolor and corrode copper and copper bearing alloys whereas oil "8" exhibits no such action against copper. Oil "8" is therefore an attractive material for use at lower speeds where surface finish is an important consideration.

When compounding a material such as oil "8" it is of help to know the influence that each ingredient has upon the performance of the base oil. The data of Fig. 2 show the effect of increasing the concentration of additive A and of the fatty material independently. A good choice for the concentration of additive A and of the fatty material appears to be at 10% of each, since this is located near the knee of the concentration curve. This explains how the composition of oil "8" may be established.

TABLE 2.—Low Speed Cutting Results

Undeformed chip thickness, 0.005 in: rake angle, 10°; clearance angle, 5°; cutting speed, 1 ipm; work material, plain carbon steel of 0.08 C content; tool material, M-2 HSS.

No.	Fluid	h, μ (in.)	F_p (lbs.)	F_Q (lbs.)	r	r (in.)	F_Q/F_p
1	Carbontetrachloride	15	252	25	.40	.03	.10
2	Trichloroethane	15	307	45	.32	.07	.15
3	Water	34	3'3	72	.29	.09	.20
4	2.5% Soluble Oil D	42	337	57	.31	.08	.18
5	2.5% Soluble Oil E	30	325	60	.30	.08	.19
6	Mineral oil	175	392	120	.24	.19	.31
7	Oil G[1]	59	332	62	.29	.07	.19
8	10% Additive A + 10% Fatty Acids in Mineral Oil	56	317	46	.33	.06	.15
9	Air	175	430	130	—	—	.30

[1]Commercial sulfurized oil

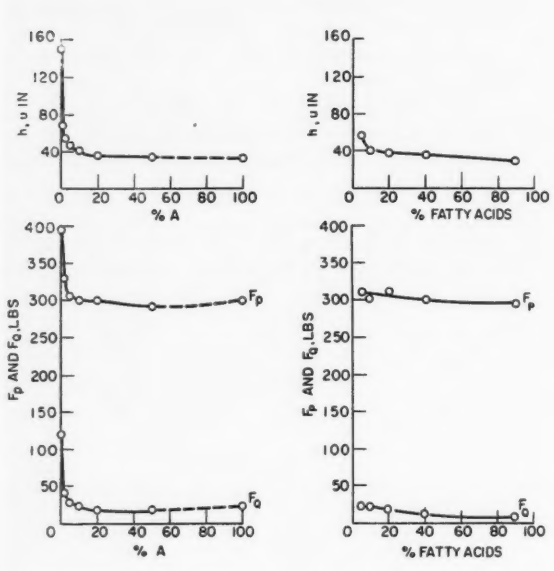


Fig. 2. Influence of additive concentration upon cutting fluid performance. Cutting conditions are the same as those of Table 2. (left) Variation of concentration of additive A in a solution of mineral oil containing a concentration of fatty acids equal to that of additive A. (right) Variation of concentration of fatty acids in a solution of 10% additive A in mineral oil.

TAPPING TEST

A tapping test can also provide a useful means for evaluating the important low speed characteristics of a cutting fluid. In the test to be discussed here a ¼-20 tap is used to tap holes until it is broken due to metal pickup and the attendant rise in tapping torque. The material tapped in these tests was a martensitic titanium alloy (4% Al 4% Mn—see Table 3). A new high speed steel spiral point tap was used in each case.

Before tapping, the dimension, roundness, and finish of the holes were carefully controlled by reaming to a diameter of 0.201 ± 0.001 inch. This hole size yielded a thread of 75% theoretical depth which represents quite a severe tapping condition for titanium in comparison with the more usual 60% thread. The thickness of the specimen was ⅝ inch. The tapping was not terminated until the first full thread of the tap penetrated all the way through the workpiece.

The specimen with holes accurately reamed was mounted on a floating table that permitted alignment of the center of the hole with the center of the tap. The tapping tests were carried out in an automatic tapping set-up at a speed of 267 rpm (17.5 fpm). The tap was attached to a strong and rigid tap holder. When the tap reached the predetermined depth of penetration, the spindle reversed its direction of rotation automatically and backed the tap out. About two milliliters of experimental fluid were used in tapping each hole, one milliliter to wet the hole and one milliliter to wet the tap. The amount of fluid used per tapping operation was not found to be critical, provided it was sufficient to completely wet the tap and hole.

The effectiveness of a fluid was determined by the number of holes that could be tapped before failure by fracture. On the average, three taps were used for each fluid and if the variation was less than five holes, the largest number of holes that could be tapped before failure by fracture was used to indicate the effectiveness of the fluid.

Table 4 lists in order of increasing effectiveness the tapping data obtained with a 10% concentration of each additive by weight in mineral oil. The four ball data obtained with 440 stainless steel balls are also tabulated in Table 4 for a 1% concentration additive.

Table 5 gives the tapping performance of various additives used without dilution. A photograph of a tap is given in Fig. 3a after tapping over fifty holes using cutting oil additive A. Fig. 3b is a photograph of another tap after tapping the second hole with a poor cutting fluid, showing extensive smear and a big fragment of titanium welded to the trailing edge during backing-out.

TABLE 3.—Chemical Composition and Physical Properties of Titanium Alloy Used in Tapping Studies

Typical chemical analysis of 4 Al-4 Mn titanium

C	N_2	Fe	Al	Mn	H_2
0.04	0.02	0.25	4.0	4.0	50 ppm

Typical mechanical properties of 4 Al-4 Mn titanium

Yield point	140,000 psi
Ultimate strength	160,000 psi
Elongation	15%
Reduction in area	45%
Hardness	36 R "C"

TABLE 4.—Performance of Various Additives at 10% Concentration in Tapping 4Al-4Mn Titanium Alloy

Additives	Number of holes tapped before breaking tap[1]	Wear scar, mm[2]
$(C_4H_9O)_3P$	1	0.4
Carbon Tetrachloride	2	2.5
$[ClCH_2CH(CH_3)O]_3P$	2	0.4
Additive B	7	0.4
Additive A	20	0.45

[1]For 10% concentration by weight in mineral oil and 4Al-Mn Ti alloy specimens.

[2]For 1% concentration by weight in mineral oil and stainless steel specimens.

TABLE 5.—Performance of Undiluted Additives in Tapping 4Al-4Mn Titanium Alloy

Additive	Number of holes tapped with neat additive
Commercial Additive C	5
Commercial Additive D	5
Additive A (50 wt. % in 2-ethylhexyl sebacate)	41
Additive A	Over 50
Carbon tetrachloride	Over 50

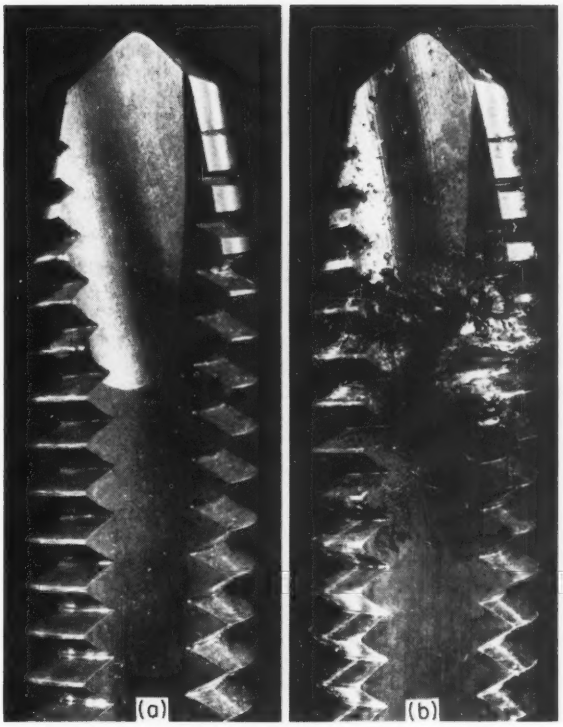


Fig. 3. Photographs of tools used to tap 4Al-4Mn titanium alloy. (a) After tapping 50 holes using additive A. (b) After tapping two holes dry.

TOOL WEAR

A cutting fluid additive that passes the screening tests for relatively low speed, wear and finish performance must provide tool life results at higher values of cutting speed that are at least as good as those obtained with an uncompounded oil, if the additive is to enjoy universal acceptance.

At high values of cutting speed the temperature has an important influence upon tool life and the role of the cutting fluid in this regime is primarily that of a *coolant*. It is commonly believed therefore that the greater the degree of cooling the better will be the cutting fluid for high speed turning operations. For this reason water-base cutting fluids are predominantly used at higher cutting speeds.

It is not difficult to demonstrate that the greatest degree of cooling does not always give the best tool life results for high speed tools and the data presented in Fig. 4 illustrate this point. These curves show the rate at which the wear land on the clearance face (w) develops with cutting time (tc) when turning with an M-2 HSS tool, having the following geometry:

back rake angle,	0
side rake angle,	15
end relief angle,	10
side relief angle,	10
end cutting edge angle,	10
side cutting edge angle,	20
nose radius	0.030

The feed, speed and depth of cut are as indicated beneath each figure. The rate of wear with water is seen to be considerably higher than that for a dry tool. Commercial water-base cutting fluids will lie in the vicinity of the water solution curve while oils containing additives lie in the vicinity of the dry curve, and beneath this curve if the additive is an effective one.

The data shown in Fig. 5 suggest that water and water solutions are *overcooling* the chip in these cases. Results for cutting oil "8" of Table 2 (10% additive A, 10% fatty acids in mineral oil) are also included in Fig. 5. The effect of changing the percentage of additive A and of the fatty acids (present in equal amounts in each case) is shown in Fig. 6. Here it is seen that the concentration previously adopted (10% A, 10% fatty acids, 80% mineral oil) provides an effective improvement to the mineral oil in each case.

The foregoing results allow the paradoxical observation that the best coolant (water) can give the highest rate of wear land development even when the tools are operating in a speed range where the temperature of the wear land is known to be of utmost importance. However, this perplexing problem can be resolved by use of a tracer instrument recently developed at MIT, which enables the shape of the crater on the tool face to be recorded as wear proceeds. Each time the wear land is measured a diamond stylus is drawn across the tool face and the shape of the build-up and crater on this face is recorded. The vertical magnification of motion is made five times the horizontal value in order to allow craters to be more conveniently represented.

Representative crater traces are presented in Fig. 7 for tools machining AISI 1020 steel at 450 fpm. The tool face surface is horizontal while the tool flank is the right hand vertical surface. The traces obtained when cutting dry are shown at (b) while those using water as the cutting fluid are shown at (a) for different values of cutting time. Wear land plots are also included in Fig. 7, and the numbers next to each test point correspond to the numbers of the crater traces. At the points indicated the clearance face of the tool was carefully reground so as to decrease the extent of the wear land without disturbing the crater on the tool face. From these results it is evident that the rate is dependent on the shape and size of both the wear land, and crater.

The crater produced with water is seen to form more rapidly than when cutting dry.

The craters that are produced when cutting dry and with water are shown superimposed in Fig. 8 for a cutting time of 9 minutes. Since it is expected that the point of maximum tool face temperature lies close to the center of the crater, the point of maximum temperature is in a better position to conduct heat to the wear land when the cutting fluid is water (due to its greater depth after a given amount of cutting) than when cutting dry. Thus, even though the water carries some heat away from the wear land, it simultaneously shifts the maximum temperature to a point where it is more effective in causing heat to flow into the wear land. The latter of these two effects appears to be the predominant one.

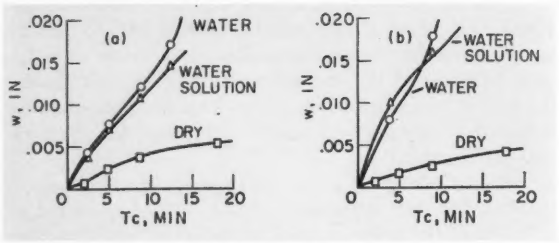


Fig. 4. Variation of wear land (w) with cutting time (Tc). (left) Work material A.I.S.I. 1020 steel; cutting speed, 350 fpm; feed, 0.0052 ipr; depth of cut, 0.100 in. (right) Work material, A.I.S.I. 4340 steel; cutting speed, 250 fpm; feed, 0.0026 ipr; depth of cut, 0.100.

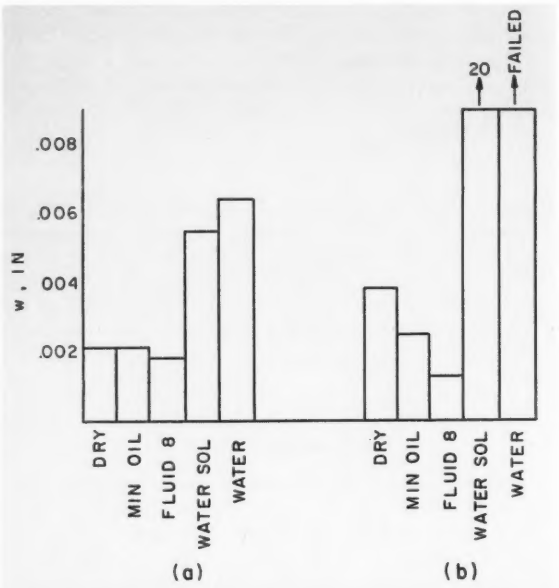


Fig. 5. Variation of wear land (w) produced in HSS tools after constant cutting time (Tc) when different cutting fluids are applied at the rate of 2.5 gpm. (a) A.I.S.I. 1020 steel cut at V = 350 fpm, t = .0052 ipr, b = 0.100 in. for Tc = 5 min. (b) A.I.S.I. 4340 steel cut at V = 250 fpm, t = 0.0026 ipr, b = .100 in. for Tc = 15 min. Fluid 8 is a mixture of 10% Additive A and 10% fatty acids in mineral oil.

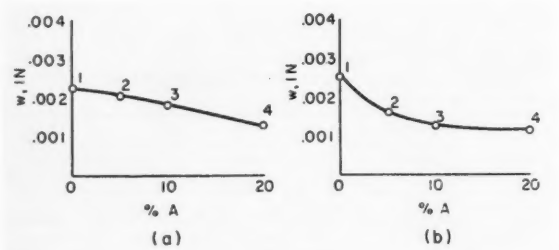


Fig. 6. Variation of wear land (w) produced on HSS tools after constant cutting time (Tc) when different concentrations of additive A are used with an equal concentration of fatty acids in mineral oil. Flow rate is 2.5 gpm in all cases. (a) A.I.S.I 1020 steel cut at V = 350 fpm, t = 0.0052 ipr, b = 0.100 in. for T = 5 min. (b) A.I.S.I. 4340 steel cut at V = 250 fpm, t = 0.0026 ipr, b = 0.100 in. for Tc = 15 min. Fluid (8) has the composition marked 3.

These results now explain a perplexing observation made some time ago (3). By causing a constantan wheel to roll on the freshly turned surface close to the clearance face of the tool it was possible to measure the temperature in the new surface soon after it was generated. It was found in some instances that this temperature would rise when water was applied to the chip and fall when dry cutting was resumed. This was apparently due to the shift in the location of the point of maximum tool-face temperature when water was applied.

Crater traces for the tests of Fig. 6 are presented in Fig. 9. Here it is evident that the fluid giving the lowest rate of wear land development (20% A, 20% fatty acids) corresponds to the one having the crater of greatest depth). For each cutting speed (and hence for each temperature level) an optimum location of the point of maximum crater depth exists. The shift of the point of maximum crater depth toward the cutting edge when the concentration of additive A is increased in Fig. 9 evidently corresponds to a shift in the direction of optimum performance.

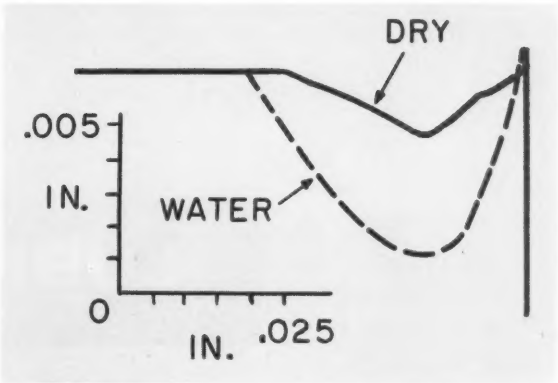


Fig. 8. Comparison of crater traces produced with and without a fluid after 10 minutes of cutting under the conditions of Fig. 7.

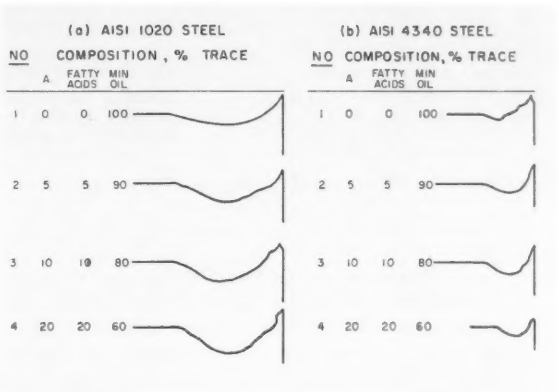

(a) AISI 1020 STEEL
NO COMPOSITION, % TRACE
A FATTY ACIDS MIN OIL
1 0 0 100
2 5 5 90
3 10 10 80
4 20 20 60
(b) AISI 4340 STEEL
NO COMPOSITION, % TRACE
A FATTY ACIDS MIN OIL
1 0 0 100
2 5 5 90
3 10 10 80
4 20 20 60

Fig. 9. Crater traces for the tests of Fig. 6 (a) A.I.S.I. 1020 steel cut at V = 350 fpm, t = .0052 ipr; b = 0.100 in. for Tc = 5 min. (b) A.I.S.I. 4340 steel cut at V = 250 fpm; t = 0.0026 ipr; b = 0.100 in. for Tc = 15 min.

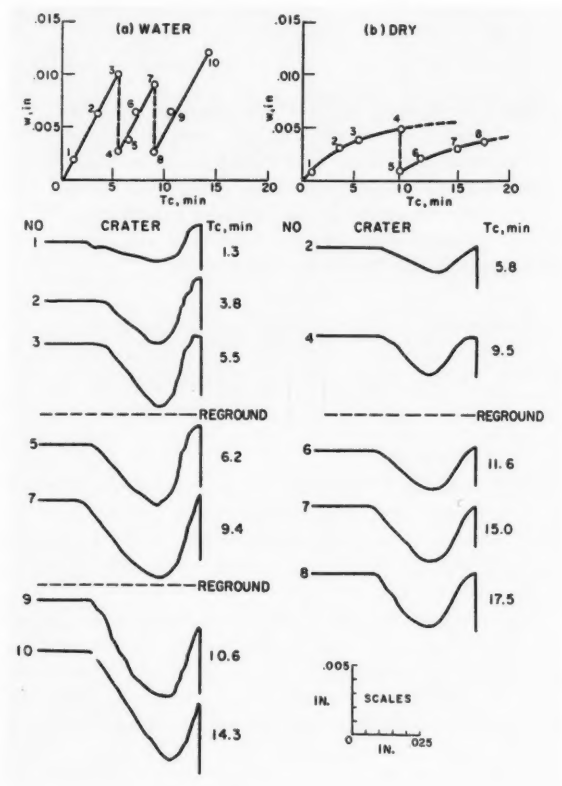


Fig. 7. Variation of wear land (w) and crater wear with cutting time. Cutting speed V, 450 fpm; feed, .0052 ipr; depth of cut, 0.100 in. Work material, A.I.S.I. 1020 steel; tool material—M-2 HSS; ASA Tool geometry: 0, 15, 10, 10, 10, 20, .03. (a) Cutting fluid, water applied at 2½ gpm. (b) Cutting fluid, none.

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ACKNOWLEDGMENTS

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Re-Refined

LUBRICATING OILS

for Railroads

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Commercial re-refiners make specification journal box oil for the railroads from used automotive crankcase oils. These oils have been drained because of contamination—the major part is NOT "worn out." Stable portions of the oil are recovered by re-refining, the unstable parts and contaminants are discarded.

Since there is no uniform specification for railroad locomotive diesel lube oil, each batch of diesel drainings must be refined to its original specification. Clean oils are refortified with heavy duty additives under railroad supervision. Many railroads then use these finished oils interchangeably with their new diesel oils.

There are two re-refined lubricating oils commonly used by railroads—Re-refined Journal Box Oil and Re-refined Locomotive Diesel Lubricating Oil.

This paper will be primarily concerned with the production of these two railroad materials by the commercial re-refiner.

Two terms should be defined: "Re-refining" will refer to complete refining of used crankcase oils by commercial re-refiners. "Reclaiming" will refer to the usually less complete processing of used crankcase oils in reclaiming units.

The first commercial re-refinery, designed and built for this specific purpose, was put into operation about 40 years ago. Railroads first used re-refined oil in journal boxes in 1943; and the first locomotive diesel oil was re-refined during 1938. By now, there are over 100 re-refiners in this country; and it is estimated that almost one-third of their total production goes to railroads.

This growth of oil re-refining has been a natural result of the expansion of the entire oil industry in response to the demands of the automotive industry.

Lube oils must be periodically drained from the crankcases of combustion engines, primarily because they become contaminated and partly because the chemical additives become depleted. Although the unstable constituents of the lube oil deteriorate during engine service, the major portion of the petroleum oil does not deteriorate—that is, it does not "wear out". Used crankcase oil must be collected and disposed of for obvious reasons. Competent refiners can process this used oil to produce railroad oils, motor oils and industrial oils.

Presented at the 15th ASLE Annual Meeting, Cincinnati, O., April, 1960.

RE-REFINED JOURNAL BOX OIL

The re-refined oil most widely used by railroads is journal box oil—commonly called Car Oil—meeting AAR Specification M-906-56 shown in Table 1.

TABLE 1.—Specifications M-906-56 Journal Box Oil

1. *Scope.*—These specifications cover journal box oil for use in saturating waste for making journal box packing, free oiling, or other uses.

Properties and Tests

2. *Properties.*—Journal box oil shall conform to the following:

Items	ASTM Method	All-Year Grade
(A) Flash, minimum	D-92	350 F
(B) Saybolt Univ. Viscosity at 210 F	D-88	53-58 sec
(C) Viscosity Index	D-567	100 min
(D) Pour Point, upper, maximum	D-97	−20 F
(E) Moisture, maximum	D-95	0.10%
(F) Pentane Insolubles	D-893	0.15% max
(G) Acidity	(Section 3)	Neutral to Methyl Orange and Phenolphthalein

Raw Material:

Used *automotive* drainings are the raw material for the manufacture of re-refined car oil. Drainings from locomotive diesel or aircraft engines are not used.

Let us consider this raw material quite carefully. Certainly it is a thoroughly contaminated mixture. The original lube oils came from many crude oil sources and were refined by various processes.

It is not generally realized that this mixture—the re-refiner's raw material—is actually a very uniform "crude oil." Bear in mind that less than two gallons is drained from the average crankcase, and less than 150 gallons is the usual pick-up per station. Thus, the re-refiner who processes 200,000 gallons of waste oil per month gets his oil from over 100,000 vehicles. It can be said this raw material is a continuous cross-section sample of the oil in all the crankcases in the country.

Armour Research Foundation is currently working on an exploratory project for the Association of Petroleum Re-refiners. One of the first steps was examination of drainings, finished oils and distillates from seven widely separated parts of this country. The Armour progress report states,

"Infrared spectra and data on physical properties were collected on the seven sets of samples.—The infrared spectra on the finished oils, ASTM Engler distillation of the distillates, and determination of the aromatic content in the distillates all support the conclusion that the various drainings from the different parts of the country are so similar that in future laboratory work only one draining stock is necessary".

Classes of contaminants present in used crankcase oil and virgin crude oil are listed in Table 2. Although crude oil components such as gasoline, kerosene, fuel oil, wax, etc., become very useful products, they are contaminants so far as lube oil manufacture is concerned.

TABLE 2.—Classes of Contaminants Present in Used Crankcase Oil and Virgin Crude Oil

CLASS OF CONTAMINANT	USED CRANKCASE OIL	VIRGIN CRUDE OIL
1. Oil Insoluble Impurities		
a. Water	Present—free and emulsified	Present—free and emulsified
b. Water soluble salts	Present—	Present—
c. Dirt	Present—road dirt, carbon soot, lead salts, wear metals	Present—dirt, pipe scale, drilling mud
2. Oil Soluble Impurities		
a. Soluble metal soaps	Present—remnants of heavy duty additives plus metallic soaps of organic acids formed in the crankcase	Present—metallic soaps of naturally occurring organic acids
3. Hydrocarbon Impurities		
a. Light petroleum fractions	Present—raw and partially burned fuel	Present—gasoline, naphthas, fuel oil
b. Waxes	Not present	Usually present
c. Unstable, unsaturated HC	Present—"cracked" lube oil	Present—
4. Chemical Impurities		
a. Oxygen bearing compounds b. Sulfur bearing compounds c. Nitrogen bearing compounds	Present—partially burned fuel; deteriorated lube oil	Present—resins, tars, asphalt

Re-refined Lubricating Oils for Railroads.
A. M. Crittenden.

Note that all the classes of impurities present in used oil are also present in crude oil. Physical contaminants,—water, dirt, metallic soaps,—run highest (15 to 20%) in used oil. The remaining contaminants are much higher in crude oil.

Yield of re-refined lube oil is 60 to 80%, while lube oil from crude is 3 to 20%.

Re-Refining Procedures:

It is obvious that the manufacture of car oil, whether by refining of crude oil or by re-refining of used oil, must include steps and selective treatments designed to remove various undesirable materials; therefore the re-refiner's methods and procedures are the same as those which have been standard in crude oil refining.

The first and most important step in re-refining oil takes place during use in the automotive crankcase. In the combustion engine,—gasoline or diesel,—the less stable motor oil constituents inevitably deteriorate. They may oxidize, crack, or polymerize; but when they are so altered, they change from motor oil into contaminants. No oil refining method can sort out the parts of the oil that will be unstable in the engine, so well as the engine itself.

Most re-refiners have "engineered" their own equipment so that no two plants are exactly alike.

However, a thorough re-refining schedule includes four basic steps:

1. *Dehydration.* This is usually a batch operation in which raw crankcase oil is heated to about 200 F, treated with alkaline chemicals and allowed to settle. This treatment breaks emulsions and colloidal dispersion caused by heavy duty additives. At the bottom of the dehydrator will be dirt and watery sludge, next will be a layer of alkaline water and on top the clean and practically dry oil to be used in Step 2. Dehydration removes not only water, but also water soluble salts, dirt, and some dispersed metallic soaps.

2. *Acid treatment.* This is also a batch operation. From 1 to 2 per cent by volume of concentrated sulfuric acid is thoroughly mixed with dehydrated oil. Acid sludge is allowed to settle and is drawn off. In this sludge are most of the unsaturated and oxidized hydrocarbons, metallic salts, and deteriorated oil products. The top layer of sludge-free oil goes to Step 3.

3. *Distillation.* This operation is carried out in either batch or continuous systems. Maximum oil temperature varies from 525 F to 600 F. Live steam is used for stripping, and in some cases vacuum is applied. Light petroleum fractions are removed during distillation. Also, any foreign matter that will crack and/or distill at these temperatures is driven off. Sulfur and nitrogen compounds invariably accompany the overhead distillate.

4. *Filtration.* At the same time the oil is being fractionated by distillation, it is also being clarified by contact filter clay. Activated clay selectively adsorbs tarry, resinous, and dark colored impurities. Filtration thru filter press or rotary filter completes this step.

By properly controlling these four refining steps, the re-refiner makes Railroad Journal Box Oil as the residual product. Contaminants have been removed, specifications are on test; and the variable, if any, is the yield.

Two of the re-refined car oil characteristics are of special interest. Oil with Saybolt viscosity at 210 F in the 53 to 58 seconds range will have viscosity index (VI) over 100 and pour point below —20 F without the addition of VI improvers or pour depressants.

This happy situation for the re-refiner results from a series of favorable conditions. It has been found that VI improvers and pour depressants do, in part, withstand crankcase conditions and re-refining procedures to carry thru into the finished oil. Much more important, however, is the survival of the fittest during engine service and re-refining. In the engine crankcase, high VI oil constituents are more stable, in general, than low VI materials. During re-refining, the acid, high temperature, and contact clay all remove low VI portions preferentially.

When different finished lube oil stocks are mixed, there often is synergism. Good qualities are enhanced by blending and poor qualities are minimized. This is particularly true of VI and pour. For instance, mixing 90 VI oil half and half with 50 VI gives 70 for the arithmetic average, but many such oil blends will actually test 80 to 85 VI.

Sales Price:

Re-refined car oil,—All Year, non-additive grade, —sells for approximately $.21 per gallon in tankcar quantities. The six cents per gallon Federal Excise Tax does not apply to re-refined oil.

Many re-refiners can supply special seasonal viscosity ranges for summer and winter free oiling. Premium (oiliness additive) grades are also available.

RE-REFINED DIESEL LUBRICATING OIL

As railroads converted from steam to diesel locomotives, many of them started almost immediately to reclaim the used crankcase oil from their new locomotive diesels. Reclaiming units with 100 to 500 gallons per day capacity performed quite satisfactorily.

Today, however, comparatively few railroads do their own reclaiming.

The following paragraph sums up the situation quite accurately. It is quoted from the current booklet "Fuels and Lube Oils for 567 Diesel Engines" distributed by the EMD Division [1].

"RE-REFINED LUBE OIL"

> "Many commercial re-refining operators are located in strategic spots in the United States, and are processing lube oil drained from diesel engines. They have complete re-refining equipment including acid treating, and in general, do a very good job of restoring the oil to its original condition when the proper concentration of additive is employed. The small scale equipment for re-refining oil without acid treating has not been adequate in many instances and obviously is a source of some concern to the oil company which supplied the product originally."

It will be recalled that in manufacturing car oil, the re-refiner pools his raw material and makes finished oil to a single specification (AAR M-906).

The procedure is quite different in the re-refining of used diesel lube oil.

The re-refiner must handle each railroad's dirty oil separately, and in some cases he must further segregate it by brands.

There is no single or uniform specification for railroad diesel engine oil. As a result, each batch of used oil must be processed to return it to the specifications of the original oil (or mixture of oils) without additives.

Batch equipment is best suited to re-refining of diesel drainings. Oil is acid treated with 2 to 4% of sulfuric acid to insure removal of additives and deteriorated oil components. In the distillation and clay contacting operation, the three variable conditions,—temperature, time and amount of steam,—must be regulated to suit the particular oil being run.

The laboratory should control each refining step to assure its optimum effect.

Finally, the clean diesel oil is stored until the railroad customer or the original oil supplier approves the batch for fortification with additive, and shipment.

What about the economics of having dirty diesel lube oil re-refined?

New diesel lube oil in tankcars costs about $.45 per gallon including tax.

The re-refining service costs 16 to 20 cents per gallon of clean oil. Add 6 to 7 cents for additive and 3 to 5 cents for railroad handling charges and there still is a handsome savings available.

A large item in the re-refiner's charge is the cost of doing business in small segregated batches requiring numerous storage tanks. The day may come when railroads will allow their dirty diesel oils to go into the re-refiner's common pool from which each railroad would receive its respective share at a lower cost.

The AAR, Purchases & Stores Division, Subcommittee on Diesel Lubricating Oil developed the following information concerning actual railroad practice from a 1958 questionnaire sent to its 25 member roads[2].

Reclaiming of crankcase drainings:

1. Ten roads have their oil re-refined by outside concerns.
2. Five roads do their own re-refining.
3. Four roads re-refine some in their own plant and some outside.
4. One road does not reclaim—Maintenance of Way Department uses for lubricating moving parts of switches, etc.

Uses of reclaimed oil:

1. Nineteen roads use as diesel lubricating oil.
2. One reports used in switchers only.
3. One road uses only in locomotives out of warranty.

Mixing of reclaimed oil with new oil for diesels.

1. Eighteen roads report they mix with new oil.
2. One road does not mix.

If new oils are not mixed and drainings are reclaimed, is the same additive restored to the reclaimed oil:

1. Twelve roads report the same additive is restored.
2. One road does not use additives in reclaimed oil.
3. Five use only one additive in all brands reclaimed.
4. One does not use the same additive.

In conclusion, these points should be emphasized:

Lubricating oil becomes contaminated during use in engine crankcases, and must be drained periodically.

Engines themselves deteriorate the less stable portions of the oil.

The stable part is recovered by re-refining, the unstable part and contaminants are discarded.

Railroads use two re-refined oils which constitute an important part of the re-refiners' production.

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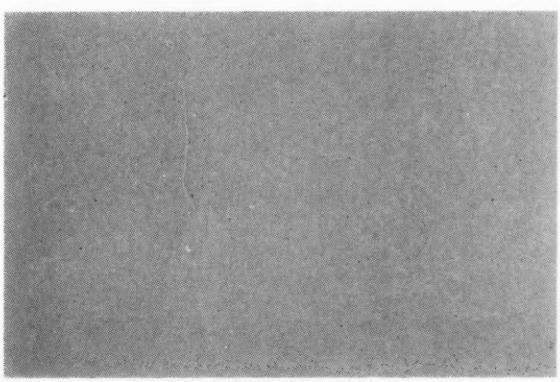

Evaluation of

RUST PREVENTIVES

for Ferrous Alloys

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Aluminum Company of America
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A test procedure is given for use in evaluating rust preventives for ferrous alloys utilizing the humidity cabinet specified in the Government Specification JAN-H-792. Good correlation was obtained between the humidity cabinet test results and the results obtained in both indoor and outdoor field tests. On the basis of these test results, purchase specifications were set up for the aid of the author's company purchasing department for five types of rust preventives.

With the exception of the noble metals such as gold, all metals occur in nature in the oxidized state and in combination with one another. After refining, these metals tend to revert to the oxidized state, whereas the noble metals are not subject to such a reversion.

There are many conditions that cause and catalyze the corrosion of ferrous metals; however, the prime cause may be attributed to the presence of moisture and air. Technically, this phenomenon is referred to as electrochemical attack. Water and oxygen must be present on the surface for iron and steel to corrode, with water serving as the electrolyte in which electrochemical oxidation proceeds and oxygen as the precipitant oxidant which reduces to the hydroxyl ion. Numerous experimenters have shown that corrosion may be conditioned by adsorption of water vapor from the atmosphere, which leads to the formation of a multimolecular water layer, playing the role of the electrolyte. Oxygen from the air, dissolving in this water layer, reaches the metal surface and causes oxidation, while water deprived of oxygen does not (1).

Since water generally contains free oxygen, and air contains various amounts of moisture depending upon the humidity, both water and air generally should be excluded from the surface of ferrous metals to avoid electrochemical attack. The corrective measures necessary to prevent the electrochemical attack of ferrous metals are generally applicable to other causes of corrosion (2).

Effective protection against rusting of ferrous metals generally can be obtained by application of rust preventives such as petroleum base oils and greases. To be effective, these materials must form an effective barrier against moisture.

A number of years ago a need was recognized by the author's company for a relatively simple test procedure which could be used for selecting and purchasing rust preventives. In view of this need, a project was undertaken to establish, if possible, the characteristics of representative commercially available rust preventives for tool steels and spare mechanical elements. In addition, such a project would standardize the usage of such materials and simplify the number and types purchased and carried in inventory. Accordingly, a preliminary program of investigation of a cross-section of representative materials was undertaken in which the relative protective values of these materials, for steels, were evaluated by means of a laboratory humidity cabinet test.

HUMIDITY CABINET TEST

The humidity cabinet selected for this program was the cabinet specified in the National Military Establishment Specification JAN-H-792 (3). This specification was written to cover the apparatus, materials, and procedure to be used in the humidity cabinet corrosion test of materials intended as corrosion preventives. The humidity cabinet is intended to produce a moisture saturated atmosphere with continuous condensation on the test specimen. A view of the inside of the cabinet is shown in Fig. 1.

The Research Division X of ASTM D-2 Committee has under consideration a similar humidity cabinet test procedure for the evaluation of rust preventives for ferrous alloys.

1. Preparation of Panels

Cold rolled SAE 1020 steel panels, $\frac{1}{8}$ x 2 x 4 inch, with two holes drilled at opposite corners of the 4-inch side, were degreased with naphtha and given a final rinse in clean solvent. For each test, three polished and three sandblasted panels were used. The polished panels were ground to a 6-12 microinch (RMS) finish with all the grinding marks parallel to the 4-inch dimension. The sandblasted panels were sandblasted with clean, dry, white, lake sand and placed in a desiccator immediately after sandblasting. After the original degreasing procedure, the panels were handled with tongs, clean cotton gloves, or suspension wires. Preceding the coating of the panels, they were given a final rinse in a solvent consisting of equal parts absolute methyl alcohol and isopropyl alcohol.

2. Application of Coating

The method of applying the coating to the steel panels varied according to the types of rust preventive being tested. These variations were as follows:

(a) Oil Coatings

Three panels were dipped in the test oil at room temperature, 25 C (77 F) and allowed to drain for two hours at that temperature.

(b) Non-Hardening Grease Coatings

In order to obtain uniform coatings, the non-hardening greases were applied by immersing the panels in the hot coating and removing the panels from the hot coating at a rate of three inches per minute. A mechanical dip coater was used for this purpose. A coating thickness of 0.003 inch $\pm$ 0.0005 inch was used in the tests and the thickness of the coating was regulated by controlling the temperature of application. In such cases where the melting point of the grease made the hot dip method of application impractical, the coating was applied as evenly as possible to the panels with a spatula.

(c) Semi-Hard Grease (Hot Dip Type Coatings)

Uniform coatings having a thickness of 0.003 inch $\pm$ 0.0005 inch were applied by immersing the panels in the hot coating material and removing the panel from the hot coating at a rate of three inches per minute. Although this removal rate did not follow any particular government specification, it was adequate for this work.

(d) Semi-Hard Grease (Solvent Cut-Back) Coatings

Uniform coatings having a thickness of 0.003 inch $\pm$ 0.0005 inch were applied by immersing the panels in the coating material at room temperature and removing the panels at a rate of three inches per minute. If necessary, several coats were applied to obtain the desired thickness.

(e) Strippable Coatings

Uniform coatings having a thickness of 0.10 inch $\pm$ 0.01 inch were applied by immersing the panels in the hot coating material and removing the panels at a rate of three inches per minute.

3. Exposure

The test panels were suspended in the humidity

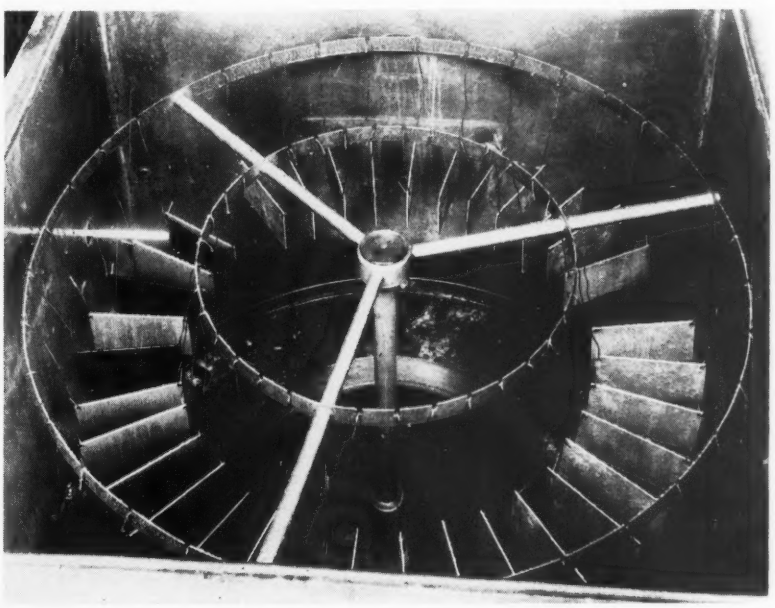

Fig. 1. Inside View of Humidity Cabinet

cabinet by two 18-8 stainless steel hooks. The humidity cabinet was operated with a relative humidity of 100 per cent at a temperature of 49 C ± 1 C (120 F ± 2 F). The cabinet was opened for a ten-minute period every 24 hours.

4. Examination of Panels

The panels were examined for the existence of rust in the significant area at prescribed intervals. The significant area was the center of the panel on both sides to within ¼ inch of the edges. Two or more rust spots or one rust spot having a diameter of more than two millimeters in this significant area was considered failure of the coating. Any rust appearing anywhere within ¼ inch of the edges was disregarded.

When this program was started in 1948 the ¼ inch margin around the panel was adopted in order to take care of any edge effect. When the JAN-H-792 Specification was issued in June, 1949, specifying ⅛ inch margin at top and bottom and ¼ inch at sides, these changes were not made since this work did not attempt to meet any particular government specification.

The panels with the oil coatings were examined visually every 24 hours. The panels with the other four types of coatings were examined by removing one panel from the cabinet after 25, 50, and 100 days and removing the coating from the panels before examination. If any panel disclosed evidence of failure caused by rusting before the 100 day exposure period, the test was terminated at that point. Aluminum panels were used to fill any blank space existing in the cabinet.

FIELD TESTS

As a second phase of the program, the humidity cabinet data were calibrated in terms of field operating data by means of small scale exposure tests in several key plants. The plants selected for these tests were Davenport (Iowa), Massena (New York), and Point Comfort (Texas). In addition, from the data obtained in these field tests under actual field conditions, knowledge of those materials of outstanding performance might possibly be obtained so that they could be expected to give satisfactory results at all plants.

Representative coatings from the five basic types were chosen for the field tests on the basis of their performance in the humidity cabinet test. Included in the test were coatings that rated superior (lasting 100 days or over in the humidity cabinet except for oil coatings, which lasted 75 days or over), intermediate (lasting 50 to 99 days in the humidity cabinet), and poor (lasting less than 50 days in the humidity cabinet).

1. Test Procedure

(a) Preparation of Panels

Polished and sandblasted in the same manner as the panels used in the humidity cabinet test, cold rolled SAE 1020 steel panels (2 x 4 x ⅛ inch) were coated with the various substances in triplicate. As in the case of the humidity cabinet tests, the non-hardening greases, semi-hard (hot dip) greases, and the strippable coatings were applied to obtain uniform coatings by immersing the panels in the hot coating materials and removing the panels at the rate of three inches per minute. A mechanical dip coater was used for this purpose and a coating thickness of 0.02 inch ± 0.005 inch was applied.

The coated panels were mounted on 3½ x 3½ foot wooden test racks with steel wood screws. A ¼ inch mesh aluminum screen wire was placed over the panels for protection. Six racks were made up so that each test location would have one for exposure outdoors and one for exposure indoors.

(b) Exposure and Examination of Coated Panels

The outdoor panels were exposed for a period of 24 months. During this period the panels were examined every three months. Panels were removed from the outdoor test racks when they became completely covered with rust. At the end of 12 and 24 months, one panel from each set still remaining on the test frames was removed, the coatings were completely stripped from the panels, and the panels were examined for signs of rust on the significant area.

The indoor panels were exposed for 72 months and were examined every three months during the first four years and every six months during the last two years. At the end of 2, 4, and 6 years, one panel from each set was removed, the coatings were completely stripped from the panels, and the panels were examined for signs of rust on the significant area.

The significant area on the panel is the center portion on both sides to within ¼ inch of the edges. Any rust appearing on the edges or in the area adjacent to the screw holes was disregarded.

The exposure stations were selected as being typical for each location. A description of each station and a summary of the weather conditions during the exposure period for each station are given in Appendix A.

EXPERIMENTAL RESULTS AND DISCUSSION

A summary of the results of the evaluation of twelve representative coatings from the five basic types in the humidity cabinet are given in Table 1. The results of the exposure of these same coatings for 24 months at the three outdoor stations are given in Table 2. The results obtained with these coatings after exposure for 72 months at the three indoor stations are given in Table 3. The results in Tables 2 and 3 are reported in degree of protection in months time. The degree of protection is broken down into four categories, which are defined as follows:

1. Completely rusted.
2. Medium rust—large patches of rust.
3. Light rust—several small spots or patches.
4. Complete protection—exclusive of area adjacent to screw holes or edges.

In general, as shown in Table 4, good correlation was obtained between the humidity cabinet test results and the results obtained in both the indoor and outdoor field tests. In other words, coatings rating poor in the humidity cabinet generally failed first on the test racks, and coatings that rated superior in the humidity cabinet gave the best performance on the test racks.

Point Comfort, Texas, which is located on Lavaca Bay on the Gulf Coast some 135 miles south of Houston, appeared to have the most severe exposure for both the indoor and outdoor stations. Massena, New York, which is located on the St. Lawrence River in northern New York, had the mildest exposure.

In general, with several exceptions, little or no difference was detected between the performance of the sandblasted or polished panels. In all but one of these exceptions, the polished panels were more susceptible to rusting than the sandblasted panels.

In the humidity cabinet test, contrary to the experience of some other investigators, no trouble was experienced with staining of the panels. Therefore, unless definite rust spots appeared on the panels, the coatings were not failed.

On the basis of these test results the following purchase specifications have been set up for the aid of the purchasing department for each of the five types of rust preventives:

TABLE 1.—Results of Humidity Cabinet Test

COATING	TYPE OF COATING	CLASSIFICATION ACCORDING TO HUMIDITY CABINET TEST	RESULTS
A	Oil	Poor	Failed after 1 day
B	Semi-Hard Grease (Solvent Cut-Back)	Intermediate	Failed between 50 and 100 days
C	Semi-Hard Grease (Solvent Cut-Back)	Superior	Passed 100 days
D	Semi-Hard Grease (Solvent Cut-Back)	Superior	Passed 100 days
E	Semi-Hard Grease (Hot Dip)	Poor	Failed after 1 day
F	Semi-Hard Grease (Hot Dip)	Intermediate	Failed between 50 and 100 days
G	Semi-Hard Grease (Hot Dip)	Superior	Passed 100 days
H	Non-Hardening Grease	Poor	Failed after 4 days
I	Non-Hardening Grease	Poor	Failed after 22 days
J	Strippable	Poor	Failed after 1 day
K	Strippable	Intermediate	Failed between 50 and 100 days
L	Strippable	Superior	Passed 100 days

TABLE 2.—Outdoor Tests—24 Months' Exposure

COATING	LOCATION OF TEST FRAME	POLISHED PANELS	SANDBLASTED PANELS
A	Davenport	Completely rusted in 3 months	Completely rusted in 3 months
"	Massena	"	"
"	Point Comfort	"	"
B	Davenport	Completely rusted in 9 months	Completely rusted in 9 months
"	Massena	"	"
"	Point Comfort	Completely rusted in 3 months	Completely rusted in 3 months
C	Davenport	Light rust in 15 months	Light rust in 18 months
"	Massena	Complete protection	Complete protection
"	Point Comfort	Completely rusted in 12 months	Medium rust in 3 months
D	Davenport	Complete protection	Complete protection
"	Massena	"	"
"	Point Comfort	"	"
E	Davenport	Completely rusted in 3 months	Completely rusted in 3 months
"	Massena	"	"
"	Point Comfort	"	"
F	Davenport	Completely rusted in 9 months	Completely rusted in 9 months
"	Massena	"	"
"	Point Comfort	Medium rust in 21 months	Complete protection
G	Davenport	Complete protection	"
"	Massena	"	"
"	Point Comfort	"	"
H	Davenport	"	"
"	Massena	Medium rust in 15 months	"
"	Point Comfort	Complete protection	"
I	Davenport	Medium rust in 24 months	Medium rust in 24 months
"	Massena	Medium rust in 15 months	Complete protection
"	Point Comfort	Light rust in 21 months	Medium rust in 21 months
J	Davenport	Completely rusted in 3 months	Completely rusted in 3 months
"	Massena	"	"
"	Point Comfort	"	"
K	Davenport	Complete protection	Complete protection
"	Massena	Complete protection	Complete protection
"	Point Comfort	"	"
L	Davenport	"	"
"	Massena	"	"
"	Point Comfort	"	"

TABLE 3.—Indoor Tests—72 Months' Exposure

COATING	LOCATION OF TEST FRAME	POLISHED PANELS	SANDBLASTED PANELS
A	Davenport	Completely rusted in 21 months	Completely rusted in 21 months
"	Massena	Complete protection	Complete protection
"	Point Comfort	Medium rust in 72 months	Medium rust in 72 months
B	Davenport	Complete protection	Complete protection
"	Massena	"	"
"	Point Comfort	"	"
C	Davenport	"	"
"	Massena	"	"
"	Point Comfort	"	"
D	Davenport	"	"
"	Massena	"	"
"	Point Comfort	"	"
E	Davenport	Medium rust in 24 months	Medium rust in 24 months
"	Massena	Medium rust in 42 months	Light rust in 24 months
"	Point Comfort	Medium rust in 30 months	Medium rust in 39 months
F	Davenport	Complete protection	Complete protection
"	Massena	"	"
"	Point Comfort	"	"
G	Davenport	"	"
"	Massena	Light rust in 72 months	"
"	Point Comfort	"	Light rust in 72 months
H	Davenport	Complete protection	Complete protection
"	Massena	"	"
"	Point Comfort	"	"
I	Davenport	Complete protection	Complete protection
"	Massena	"	"
"	Point Comfort	"	"
J	Davenport	Completely rusted in 3 months	Completely rusted in 3 months
"	Massena	"	"
"	Point Comfort	"	"
K	Davenport	Complete protection	Complete protection
"	Massena	Complete protection	Complete protection
"	Point Comfort	"	"
L	Davenport	"	"
"	Massena	"	"
"	Point Comfort	"	"

TABLE 4.—Comparison of Humidity Cabinet Test and Field Test Results

COATING	CLASSIFICATION ACCORDING TO HUMIDITY CABINET TEST	CLASSIFICATION ACCORDING TO FIELD TESTS	
		OUTDOOR	INDOOR
A	Poor	Poor	Poor to Superior
B	Intermediate	Intermediate	Superior
C	Superior	Intermediate to Superior	Superior
D	Superior	Superior	Superior
E	Poor	Poor	Poor
F	Intermediate	Intermediate	Superior
G	Superior	Superior	Intermediate to Superior
H	Poor	Intermediate to Superior	Superior
I	Poor	Intermediate	Superior
J	Poor	Poor	Poor
K	Intermediate	Superior	Superior
L	Superior	Superior	Superior

NON-HARDENING GREASE COATING

This rust preventive is intended to be used for the temporary protection of steel stocks and spare mechanical elements during indoor storage for periods up to three years and outdoor storage for periods up to two years.

A representative sample of the coating must exceed or meet the following requirements:

(a) Unworked Penetration/77 F—200 min., 350 max.
(b) Dropping Point °F—120 min.
(c) Humidity Cabinet Test—The coating must successfully pass a humidity cabinet test having a relative humidity of 100 per cent at 120 F after 100 days' exposure.

SEMI-HARD GREASE COATING (HOT DIP TYPE)

This rust preventive is intended to be used for the temporary protection of steel stocks and spare mechanical elements during indoor storage for periods up to three years and outdoor storage for periods up to one year.

A representative sample of the coating must exceed or meet the following requirements:

(a) Flash Point °F—350 min.
(b) Removal—The coating shall be readily removed by means of a solvent such as mineral spirits.
(c) Unworked Penetration/77 F—25 min., 175 max.
(d) Dropping Point °F—135 min.
(e) Humidity Cabinet Test—The coating must successfully pass a humidity cabinet test having a relative humidity of 100 per cent at 120 F after 100 days' exposure.

SEMI-HARD GREASE COATING (SOLVENT CUT-BACK)

This rust preventive is intended to be used for the temporary protection of steel stocks and spare mechanical elements during indoor storage for periods up to three years and outdoor storage for periods up to one year.

A representative sample of the coating must exceed or meet the following requirements:

(a) Flash Point °F—100 min.
(b) Removal—The coating shall be readily removed by means of a solvent such as mineral spirits.
(c) Humidity Cabinet Test—The coating must successfully pass a humidity cabinet test having a relative humidity of 100 per cent at 120 F after 100 days' exposure.

STRIPPABLE COATING

This rust preventive is intended to be used for the temporary protection of steel stocks and spare mechanical elements during indoor storage for periods up to three years. In addition, the coating shall give substantial protection to cutting edges and other parts needing mechanical protection against abrasion or impact.

A representative sample of the coating must exceed or meet the following requirements:

(a) Strippability—The coating must be readily and completely strippable after extended storage.
(b) Flash Point °F—400 min.
(c) Humidity Cabinet Test—This coating must successfully pass a humidity cabinet test having a relative humidity of 100 per cent at 120 F after 100 days' exposure.

OIL COATING

This rust preventive is intended to be used for the temporary protection of steel stocks and spare steel mechanical elements during indoor storage for periods up to one year.

A representative sample of the coating must exceed or meet the following requirements:

(a) Viscosity SSU/100 F—1500 max.
(b) Pour Point °F—+5 max.
(c) Flash Point °F—300 min.
(d) Humidity Cabinet Test—The oil must successfully pass a humidity cabinet test having a relative humidity of 100 per cent at 120 F after 75 days' exposure.

CONCLUSIONS

1. Good correlation was obtained between the humidity cabinet test results and the results obtained in both the indoor and outdoor field tests.

2. In general, with several exceptions, little or no difference was detected between the performance of the sandblasted and the polished panels. In all but one of the exceptions, the polished panels were the most susceptible to rusting.

3. Point Comfort, Texas, was the most severe exposure for both the indoor and outdoor stations. Massena, New York, had the mildest exposure.

4. On the basis of these tests, purchase specifications were set up for the aid of the purchasing department for each of the five types of rust preventives.

ACKNOWLEDGMENT

The contributions of the following people in this program are acknowledged: R. B. Walker, C. L. Huey, T. B. Murphy, and R. O. Lovendahl.

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APPENDIX A

A Descriptive of Each Station Location and a Summary of the Weather Conditions During the Exposure Period

Davenport, Iowa

The outdoor rack was located in a fenced-in electrical receiving station. As shown in Fig. 2, the rack was installed at an angle of 45 degrees on a wooden stand about three feet from the ground facing west, since most of the storms in this area come from the west.

The first three-month exposure period was during the winter and the temperature fell to as low as —18 F. There were a number of severe rains and three or four hot days during the second three-month period. During the third three-month period, there was considerable rain and the temperature was below normal for summer. During the fall months, the fourth three-month exposure period, the panels were subjected to a period of high humidity as well as some below freezing weather. The fifth three-month exposure period or second winter was generally cold with high humidity and several heavy snow falls. There were several rainy spells during the sixth three-month exposure period. The second summer or seventh three-month expoure period was hot and humid with temperatures as high as 95 F. There were three hard rains and several showers. The eighth three-month period was generally warm and dry with some frost at night.

The indoor rack was located on the north wall of a building having a typical humid mill atmosphere in such a position that it could be inspected from the overhead crane.

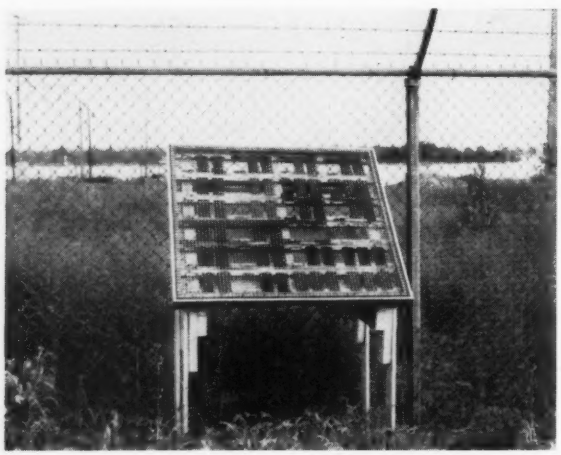


Fig. 2. Outdoor Exposure Station at Davenport Works

Massena, New York

The outdoor rack was installed at an angle of 45 degrees on a wooden rack located on the roof of the machine shop.

The first three-month exposure period was a typical winter season. There were high winds and several hot days during the second three-month period. Spring weather came early that year. The temperature was below normal for summer and considerable rain occurred during the third three-month period. During the fall or fourth three-month exposure period, there was one very cold month and more rain than normal. The second winter or fifth three-month period was warmer than normal and there was considerable rain. There were several sleet storms, snow falls, and short sub-zero periods with temperatures as low as —28 F. The sixth three-month period was generally cool and there was rain and high winds during the last month. The second summer or seventh three-month period was fair and mild except for two weeks of rain and one severe wind storm. The eighth three-month period was unusually mild for fall and there was some rain and one light snow fall.

The indoor rack was installed on the south wall of a building having a mill atmosphere.

Point Comfort, Texas

As shown in Fig. 3, the outdoor rack was located on an atmospheric corrosion test rack located in the plant yard.

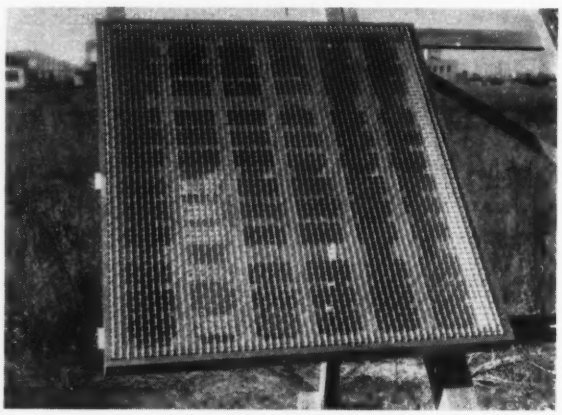


Fig. 3. Outdoor Exposure Station at Point Comfort Works

During the first three-month exposure period, the panels were subjected to one day of drenching rain, four days of sleet and freezing rain, and four days of sub-zero temperature. There was one severe rain during the second three-month period. Summer, the third three-month period, was hot and dry and there was only one rain. Numerous showers and one driving rain occurred during the fourth three-month exposure period. The temperature was moderate, averaging 50 to 60 degrees during the second winter or fifth three-month exposure period. Except for February, which had 3 to 4 inches of rain, it was generally dry. The humidity was low in December and January and higher in February. There were two light frosts. The sixth three-month period was normal for the season of the year. It was generally warm and there was one heavy rain and several light showers. The second sum-

mer or seventh three-month period was hot and dry and the temperature averaged 90 to 100 F. There was one hard driving rain for a period of two days. The eighth three-month period was generally warm and dry. There was one rain during the period.

The indoor rack was installed in the basement of the office building. However, after six months the rack was relocated on the east wall of the store room. This change was made because an air conditioning system was installed in the building and the atmosphere was not representative of the rest of the plant.

DISCUSSION

W. A. Barr,
Atlas Powder Company,
Wilmington, Delaware

The author has presented an excellent and thorough study of a laboratory type test procedure for evaluation of rust preventives—particularly in comparison with both indoor and outdoor field testing.

Bench scale testing at its best is almost always limited in results when compared with full scale field testing. The JAN-H-792 humidity cabinet, however, is one of the few laboratory testing apparatus and procedures that is quite widely accepted in industry and has proven over many years' usage to have good correlation with field data.

The following comments, suggestions, and questions are offered as constructive criticism and are based on our own experience with this particular test apparatus and method as well as work presently being carried out by ASTM Committee D-2, Research Division X, Section B on Humidity Cabinet Test studies:

1. Type and preparation of the test panels is probably one of the most important single phases of this test. For the polished panels, we have changed over from the time consuming refinishing work of panel preparation to use of new prefinished test specimens which take only degreasing for use. Both reproducibility and repeatability of our data show that this is satisfactory. The ASTM committee recommends a cleaning procedure including a room temperature alcohol rinse of the panels, a vapor degreasing over boiling ASTM precipitation naphtha, followed by a dip in boiling absolute methanol. We use a room temperature benzene dip, a boiling thiophene-free benzene dip, and a boiling 95% methanol dip.

Mr. Sawyer has indicated little difference in results between polished and sandblasted test panels, with the polished specimens being somewhat more susceptible to rusting. We have experienced the same thing and feel that polished panels are preferable for such studies.

2. It was noted that where hot dipping application of test greases was not practical, the coating was applied by spatula. Special applicators are available which would give controlled thickness application of such greases and are suggested for your trial.

3. Panels were examined every 24 hours—we presume by opening the cabinet and removing the panel to observe it for rust spots. Although it may be preferable to open the top at periodic intervals, as suggested by both the author and the ASTM committee, to give controlled condensation, visual examination of the panels can be done easier and more effectively by one change in the cabinet. As indicated in a paper entitled "The Accelerated Condensation Corrosion Test for Evaluating Rust Preventives" by Gaynor and Dieman, a double glass window about 6 in. x 15 in. in the front wall of the cabinet at panel level, allows a good view of the test surfaces at any time without disturbing the cabinet conditions.

4. Some time ago we experienced very sporadic results in our Humidity Cabinet tests. It was finally traced to contamination in the air being picked up by our laboratory compressor system—probably dissolved industrial gases which could have very adverse effect on the test panels in the cabinet. Addition of a scrubber in our air line prior to entering the cabinet has entirely overcome this problem, and we recommend such precaution for any users of this test cabinet to help standardize the method. We use a sintered glass aerator bubbling air through a bottle containing 5% sodium hydroxide plus phenolphthalein.

5. In Table 4, it is interesting to note that in only two cases (coating C and G) did the humidity cabinet rate inhibitors higher than either outdoor or indoor field tests. There were six cases where the cabinet appears to be slightly more critical than the field tests. If bench scale testing were to be weighted in either direction, I believe it is preferable to have it go this way.

As I indicated to begin this discussion, the author has shown by direct comparison with field test data, that his humidity cabinet test results are valid and quite adequate. In fact, it has been difficult to find any specific criticisms of his work. The remarks presented here are intended to merely caution others who may use this test as to areas of potential problems we have had to overcome in our test work. Again let me commend Mr. Sawyer for a project well done.

Editor's Note:

Authors are furnished a copy of each discussion and invited to submit a closure. Since no closure was submitted for the above article, it may be assumed that the author either concurred with the discussor or did not feel that a reply was necessary.

Several types of systems are available for the measurement of oil film thicknesses of the order of a few thousandths of an inch and smaller in journal bearings. This paper describes a pneumatic system and indicates the advantages of this system over some of the others.

A Pneumatic Gaging System for Measuring OIL FILM THICKNESS *in Journal Bearings*

by H. N. Kaufman

Westinghouse Research Laboratories
Pittsburgh, Pennsylvania

INTRODUCTION

Several types of measuring systems are available for the measurement of distances of the order of a few thousandths of an inch (mils) and smaller. These systems fall into one of four main types; mechanical, electrical, pneumatic, and optical, or combinations of these.

The author has found that a pneumatic system offered the following advantages over some of the other systems in measuring oil film thicknesses in journal bearings. These advantages are:

1. The ability of an air gage to make measurements to a surface without contacting the surface, thus preventing any wear or damage of either the measuring head or the work surface.

2. The measuring head has no moving parts, therefore maintenance is kept to a minimum.

3. The measuring head, which is a simple nozzle, can be made small enough to be mounted close to the point at which the measurement is desired.

4. Since the measuring nozzle can be made a separate piece and bolted close to the point of measurement or can be made an integral part of the bearing, the gage length of the system is kept to a minimum, resulting in greater accuracy than can be obtained in systems requiring gage length compensation.

5. The indicating part of the system can be placed at a convenient location up to several feet from the point of measurement.

6. An air gage system is stable in the gaging range for which it is designed, a factor which is not always true for some electrical systems.

7. The calibration of an air gage is independent of surrounding surfaces or materials which is often not the case with some electrical systems.

Typical Air Gage Circuit

Fig. 1 is a diagrammatic sketch of a simple pneumatic system which depends upon pressure as the indicating parameter rather than flow, although either may be used. The system consists of a fixed size orifice in series with a measuring nozzle. A supply pressure, P_0, is maintained by a regulator, and the air in passing through the fixed orifice decreases to pressure P_1. A further drop in pressure to P_2 occurs in passing through the nozzle and nozzle clearance, S, between the nozzle and the surface to which the measurement is taken. Any change in the distance S results in a change in the pressure drop ($\Delta P = P_0 - P_1$) across the fixed orifice. This pressure drop is measured by a manometer using mercury or other liquids depending upon the desired sensitivity.

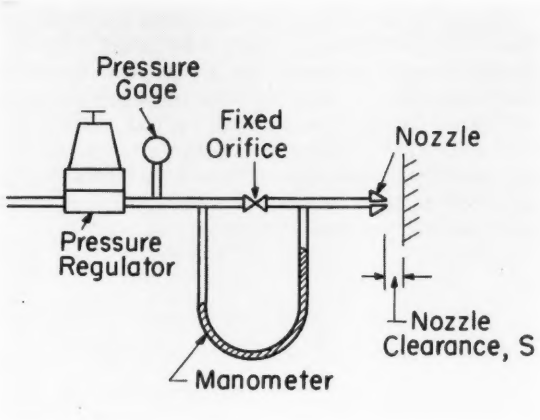


Fig. 1. Diagrammatic sketch of an air gage system

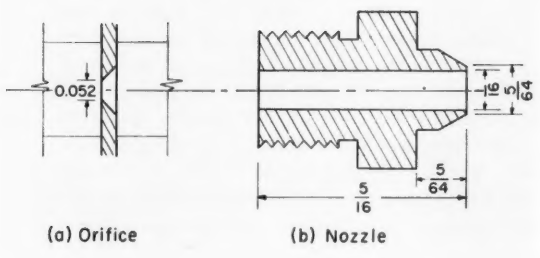


Fig. 2. A typical orifice and nozzle design

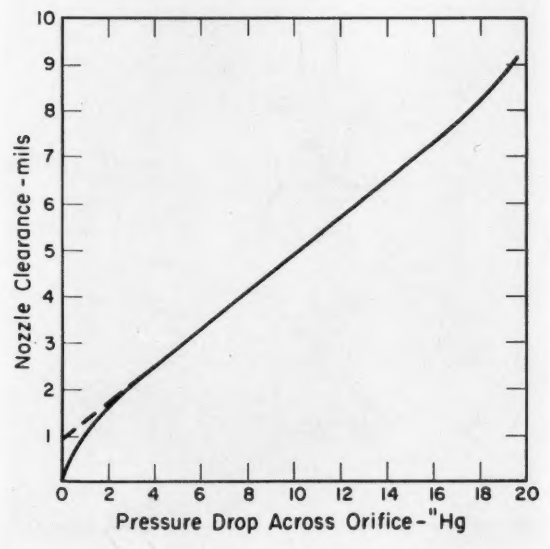


Fig. 3. A typical air gage nozzle calibration curve

Fig. 2 shows a typical orifice and nozzle design for an air gaging system. The shape of a typical calibration curve is shown in Fig. 3. The nozzle clearance or distance of the nozzle from a surface is plotted against the pressure drop across the orifice. The length of the straight portion of the curve, its slope (which gives the sensitivity of the system), and the point at which the curve becomes straight, depend upon the selection of the system parameters, i.e., supply pressure, orifice size, and nozzle design.

Factors Effecting Air Gage Readings

Under static conditions, the presence of oil on the surface to which the measurements are made, does not effect the air gage reading as long as the air jet is effective in blowing the oil from beneath the nozzle. It does not follow, however, that this is true when the surface is in motion.

Tests were conducted to investigate the effects of speed alone, oil alone, and the combination of speed and oil on the air gage readings. A nozzle was accurately set at a distance of 6 mils (0.006 in.) from the shaft of a precision spindle. The effects of the aforementioned factors on the indicated reading of the nozzle to shaft distance were observed and are shown in Fig. 4. As can be seen, oil had no effect on the nozzle clearance readings with the shaft stationary. Speed alone had a small effect, producing a decrease in the readings of 6 microinches (0.000006 in.) at 500 RPM and 27 microinches (0.000027 in.) at 5000 RPM. It is felt that if necessary this minor effect could be corrected for in the air gage calibration.

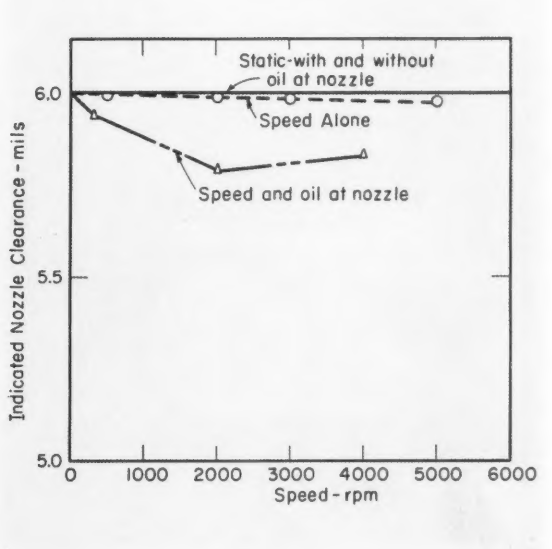
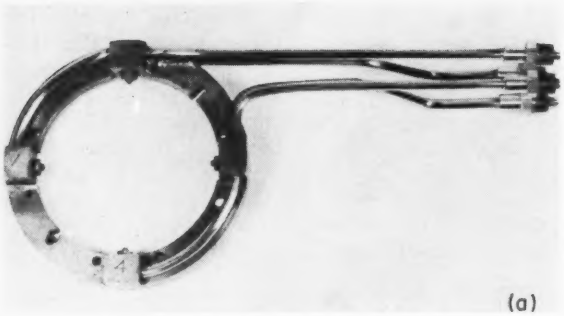


Fig. 4. Effect of speed and oil on the indicated readings of nozzle clearance



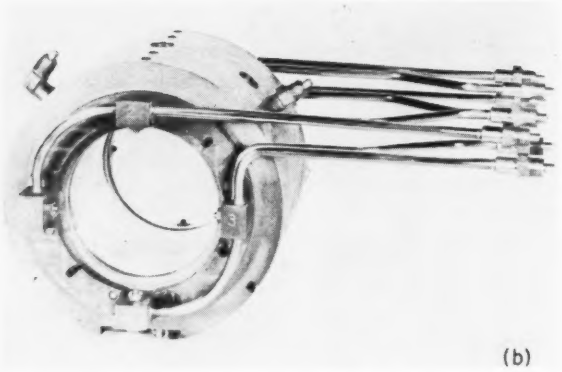


Fig. 5. Air gage fixture used on 3 in. dia. bearing
(a) Air gage fixture
(b) Fixture mounted on bearing

The most significant effect was observed when any oil on the shaft was carried by the motion of the shaft into the clearance between the nozzle and the shaft. When this occurred, the maximum indicated decrease in distance between nozzle and journal was in the order of 0.2 mil (0.0002 in.). Any error in the air gage readings due to this cause can be eliminated by incorporating a barrier or seal which will prevent oil from reaching the nozzle.

An Air Gage Applied to a Bearing

Fig. 5a shows an air gage fixture for measuring the film thicknesses at four positions at one end of a 3 inch diameter bearing. The four readings permit the calculation of the film thickness at any angular position around the bearing and also permit the calculation of any change in clearance due to thermal effects and mechanical distortion. Fig. 5b shows the air gages mounted on each end of the test bearing.

After mounting the gages, a cut, concentric with the bearing bore, is made across the face of the nozzles to provide a set-back of the nozzles, usually of the order of a few mils, from the bearing surface. The set-back prevents damage to the nozzles by the shaft and makes it possible to operate on the straight portion of the calibration curve.

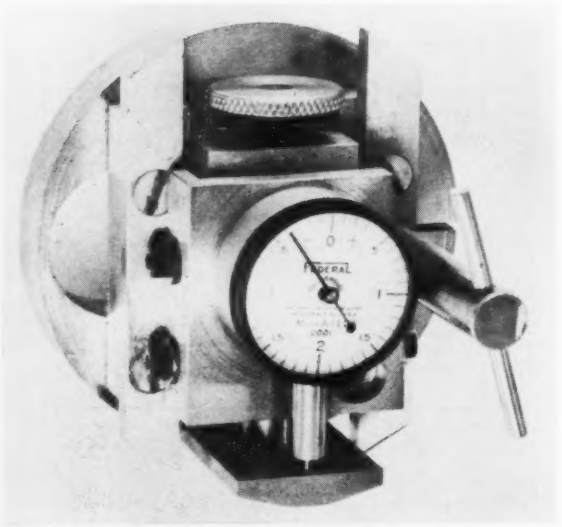


Fig. 6. Fixture for calibrating air gages

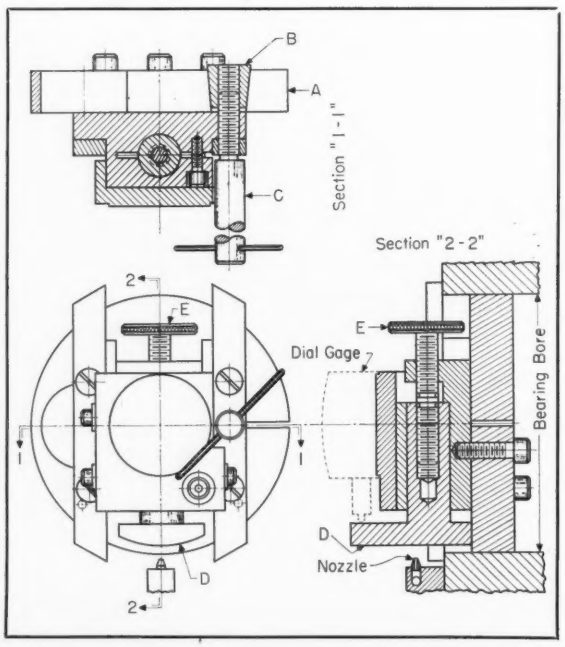


Fig. 7. Drawing of calibration fixture

Calibrating the Air Gage

Fig. 6 is a photograph of a device used for calibrating air gages mounted on a 3 in. diameter bearing. Fig. 7 is a drawing giving three views of the calibrating device and indicating the important parts. Part A is a split ring which can be expanded by the tapered plug B and the screw C to fit tightly into the bearing bore. The surface D is machined to the journal radius and may be moved by differential screw E. The amount of motion is measured by a .0001 in. graduated dial gage. This surface D is positioned over each nozzle and extends into the bearing bore. An air gage reading corresponding to the position at which the shaft is in contact with the bearing surface may be obtained by screwing the surface D down until it contacts the bearing surface. The magnitude of the air gage reading at this point will depend upon the amount of setback of the nozzle from the bearing surface, and is indicated in Fig. 8, which is an actual calibration curve for one of the nozzles. The readings corresponding to journal to bearing distances were obtained by positioning surface D at the various distances as indicated by the dial gage, taking the point at which surface D contacts the bearing surface as the zero position. The calibration curve shown in Fig. 8 was obtained using an air gage system with orifice and nozzle dimensions shown in Fig. 2 and an air supply pressure of 50 psi.

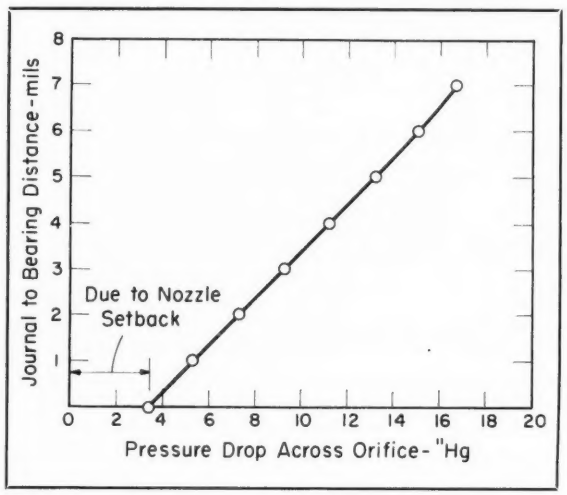


Fig. 8. Actual calibration curve for a nozzle mounted on a 3 in. diameter bearing

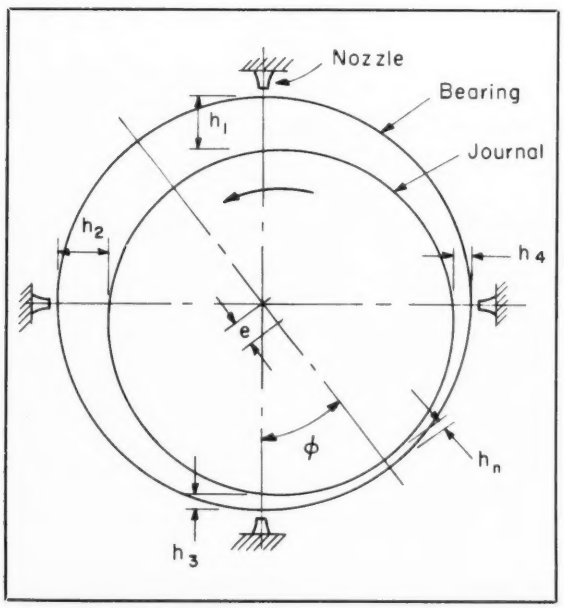


Fig. 9. Diagrammatic sketch showing a journal position within the bearing and the relative film thicknesses at the nozzle positions

Obtaining Journal Running Position with Air Gages

In operation, the diametrically opposed nozzles on one side of the bearing give readings of the distances of the journal from the bearing surface at four points on the bearing; top, front, bottom, and back. These quantities are indicated in Fig. 9 as h_1, h_2, h_3, h_4, respectively. Having obtained these values the following quantities can be calculated.

The average radial clearance, C:

$$C = \frac{h_1 + h_2 + h_3 + h_4}{4}$$

The journal eccentricity, e:

$$e = \sqrt{(C - h_3)^2 + (C - h_4)^2}$$

The minimum film thickness, h_n:

$$h_n = C - e$$

The position of the minimum film thickness, φ:

$$\varphi = \arctan \frac{C - h_4}{C - h_3}$$

CONCLUSIONS

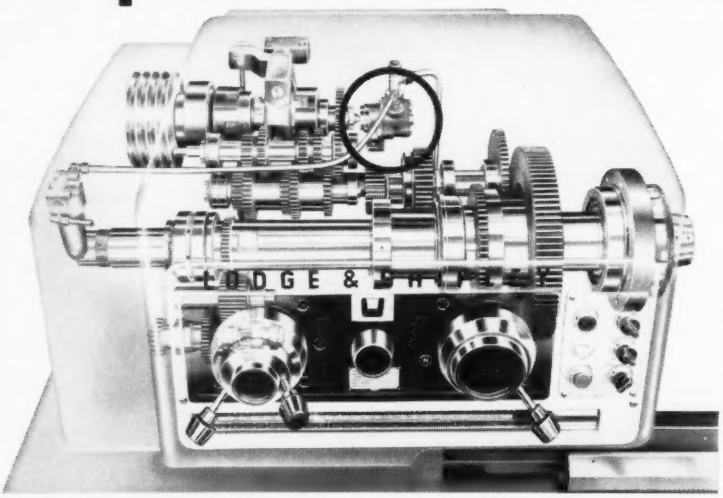
The writer feels that a pneumatic gaging system has many advantages in measuring small distances in cases which do not involve rapid fluctuations. The system which has been described in this paper has been used on various bearing tests and has performed very satisfactorily. With a reasonable amount of care, a pneumatic system will provide accurate and reliable readings.

How to select or design a pump for pressure lubrication

by E. H. Schanzlin
Chief Engineer, Tuthill Pump Company

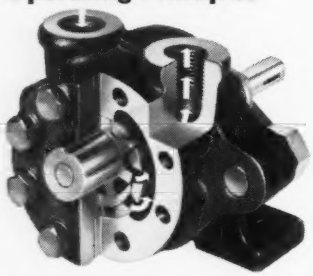
Our headline is something of a misnomer . . . for designing a pump for pressure lubrication today would be as pointless as designing a dowel pin.

Instead, there's a simple and increasingly popular answer to this problem. Practically every important manufacturer of air conditioning or large air compressors . . . manufacturers of machine tools . . . diesel engines . . . plus hundreds of manufacturers of diversified industrial equipment from valve operators to giant gear boxes . . . have selected Tuthill internal gear pumps for this demanding application because of compact size, economical price, quiet operation . . . and, above all, for their dependability, proven in over thirty years of operation.



Tuthill model ORL pump provides pressure lubrication for Lodge & Shipley POWERTURN lathes. Mounted in headstock area, this reversing pump is driven by a reversing clutch shaft, provides positive reversing action. Ports remain constant without use of valves.

Internal Gear Operating Principles



Tuthill internal gear pumps have only two moving parts. The pumping principle is based on the use of a rotor, idler gear, and a crescent shaped partition cast integral with the cover.

Power applied to the rotor is transmitted to the idler gear with which it meshes. The space between the outside diameter of the idler and the inside diameter of the rotor is sealed by the crescent.

As the pump starts, the teeth come out of mesh increasing the volume. This creates a vacuum, drawing the liquid into the pump through the suction port. The liquid fills the spaces between the teeth of the idler and the rotor, and is carried past the crescent partition to the pressure side of the pump. When the teeth mesh on the pressure side, the liquid is forced from the spaces and out through the discharge port.

Special Advantages of Reversing Pumps

Tuthill also offers a complete selection (375 models) of internal gear pumps with a special reversing feature. The unique construction of these units permits positive reversing action without the use of valves, and with the port positions remaining constant.

Reversing pumps are necessary when the lubrication pump must be driven by a reversing shaft, or when machinery must be shipped without knowing the ultimate direction of the driving unit.

A good example is shown above. A reversing pump is mounted directly on the reversing clutch shaft in the headstock area of Lodge & Shipley's POWERTURN lathes to provide dependable pressure lubrication of these outstanding machine tools.

Stripped or Cartridge Models

For extremely crowded applications, or extra economy, Tuthill also offers a complete selection of stripped and cartridge models, in which only the basic pumping elements are supplied for incorporation directly into your equipment. These units have been widely used to supply positive pressure lubrication and hydraulic power in many important applications.

Over 800 Models

Tuthill's complete selection of internal gear pumps includes over 800 different models from stock for capacities from ⅓ to 200 gpm; for pressures to 500 psi; and speeds to 3600 rpm. Specially designed housings, shaft extensions, relief valves and many other features can be developed by Tuthill engineers for specific applications.

Write for complete catalogue No. 100 . . . or send us drawings on your application so Tuthill's engineers can make specific suggestions.

Tuthill manufactures a complete line of positive displacement rotary pumps in capacities from 1/3 to 200 gpm; for pressures to 1500 psi; speeds to 3600 rpm.

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ASLE Technical Digest

Papers which, because of space limitations, cannot be published in full in Lubrication Engineering or ASLE Transactions.

"Training the User of Hydraulic Equipment," by F. L. Mackin, General Motors Institute, Flint, Michigan.

Training of plant personnel who may have to do with installation, operation and maintenance of hydraulic power systems, is a most important factor in modern industry. Today hydraulic power transmission is versatile, widely applicable and highly efficient, yet, it can become a headache if the complexities are not thoroughly understood. The author presents a comprehensive resume of the range of application, then he discusses the importance of adequate training of plant people who may be responsible for adjustment, operation and maintenance of such systems. In the planning of any educational program knowledge of design, construction and installation is basic. To this end the program must be handled by people who are thoroughly familiar with the fundamentals. In effect it is necessary for management to consider

Who must be trained
Who should do the training
The scope of the training program

Obviously those to be trained should include plant personnel who must work with the systems. They should be instructed by technicians or engineers who have thorough knowledge of the component parts of the hydraulic circuit and the relation of these parts to the system as a whole. Volumetric efficiency of pumps; coefficients of flow of various types of valves; heat generation and heat transfer, etc., are examples of details which must be stressed when the instructor explains the make-up of such a system with respect to pumps, valves, piping, packing and connections. Each must be "right" with respect to the others. Heat is most important because a hot running system is a poor investment. The author stresses the importance of developing capable training personnel at the engineering school level so that there will be an adequate supply of skilled people available to industry. At this level the scope of the training program should be established.

When capable training personnel are available they can organize in-plant training to good advantage. When this is practicable the various idiosyncracies of specific plant systems can be recorded and discussed for most complete information of the operators and maintenance personnel. Obviously the program can be most effective when the problems are presented by these people, and technical data is furnished by the equipment manufacturers, so that corrective measures can be taken before down-time for repair is required. Hydraulic standards are most important, particularly those of the Joint Industry Conference. Characteristics and applicability of hydraulic oils also must be studied; in fact it has been estimated by one equipment builder that approximately 80% of their service troubles are traceable to improper care of such oils, or to unsuitable characteristics. Laboratory study to combine theory with practice is of inestimable value. This will enable training students in the laboratory under close supervision of the instructor, on job conditions similar to those which may be encountered in the plant.

Under the caption "Hydraulics of Industrial Equipment" the author outlines the two-semester course offered by his company for cooperative engineering students. It includes

1.—The fundamentals of fluid mechanics as related to industrial equipment. Operating principles and construction of hydraulic pumps, valves, accumulators, intensifiers, fitting and tubing, oils and oil seals, and cylinder assemblies. Introduction to the manner in which the above components are assembled into typical hydraulic circuits.
2.—Laboratory work designed to acquaint the student with construction and operation of hydraulic equipment, circuits and methods of testing.
3.—Study of the construction and operation of the more advanced types of hydraulic circuits with particular attention to the design features of these circuits.
4.—The course requires the student to become proficient in designing circuits to meet definite requirements. This includes making the necessary computations, drawing schematic diagrams and describing the circuit operation. In the laboratory the student studies the construction and operation of the more complex systems with such phenomenon as surge pressure, etc. with corrective measures.

(Digested by A. F. Brewer)

What synthetic sealing materials should I use—and when

Environmental conditions generally dictate the type of synthetic rubber for a specific oil sealing application.

Where temperature, shaft speed, runout, eccentricity, and lubricant type are "normal", standard Buna N synthetic rubber compounds are satisfactory. If, however, the application is "dry running", a compound must be selected that will operate satisfactorily with a very small amount of lubricant. If the application involves excessive abrasion, highly "loaded" compound stocks should be provided. At temperatures over 250° F polyacrylics or silicone compounds are indicated; if high temperature is accompanied by a solvent base or additive lubricant, polyacrylics are definitely preferred.

Thus many variables govern successful oil sealing. The chart below gives more data; for complete information from the world's foremost oil seal laboratories, call your National Seal engineer. He's in the Yellow Pages, under Oil Seals or O-Rings.

SYNTHETIC RUBBER COMPOUNDS | **RECOMMENDED APPLICATIONS**

Comp. No.	Base Polymer	Min/Max Operating Temperature	Life Index	Price Index	Automatic Transmissions	Pinions	Axle Seals	Engine Seals	Misc. Applications
B-63	Buna N	—40°F/225°F	100	100				Excellent for small gas engines.	Excellent for small non-spring loaded seals.
B-86	Buna N	—30°F/225°F	100	100		Satisfactory for medium temperature applications.	Truck and automotive rear axles. General use.	Satisfactory as general purpose material where temperature permits.	General purpose Buna N applications.
B-94	Buna N	—60°F/250°F	100	100					Excellent against aromatics and some military aircraft oils, fuels.
B-95	Buna N	—30°F/225°F	100	100					Good dry running compounds for applications requiring high durometer stock.
C-6	Buna N	—30°F/225°F	100	100			Excellent for semi-rough axles. Has good wear qualities.		Good for pressure seals due to high durometer and clean trimming.
L-28	Acrylon BA-12	—30°F/300°F	400	125	Good for temperature range indicated.	Satisfactory in single lip construction.	Sealed bearing high temperature applications.	Satisfactory for automotive use. High temperatures.	Satisfactory for high temperature general applications. Can be used with EP or GL-4 oils.
L-34	Hycar PA-21	0°F/300°F	400	115	Good for temperature range indicated.	Dual lip limited contact for high temperatures.	Sealed bearing high temperature applications.	Satisfactory for automotive use. High temperatures.	Satisfactory for high temperature general single or dual lips. Ok with EP or GL-4 oils.
S-48	Silicone*	—80°F/400°F	1500	150	Excellent high and low temperature life.	Silicone Compounds Not Recommended With EP Lubricants at high temperatures.		Excellent for general engine use. Suggested for premium gasoline and Diesel engines.	Excellent wide range material. Avoid use in EP and GL-4 oils.
S-49	Silicone*	—80°F/300°F	600	130	Good at high and low temperatures.			Very good for general engine use; premium gasoline and Diesel engines.	Very good wide range material. Avoid use in EP and GL-4 oils.

*Silicones require special stabilization for satisfactory use in aromatic oils at high temperatures.

NATIONAL SEAL
Division, Federal-Mogul-Bower Bearings, Inc.
GENERAL OFFICES: Redwood City, California
PLANTS: Van Wert, Ohio; Redwood City and Downey, California

Lubrication Abstracts

Edited by
W. E. Campbell

Selected literature compiled by members of the Technical Committees and Industry Councils of the Society.

"Experimental Investigation of Power Loss in Journal Bearings Considering Cavitation", L. Floberg, Chalmers Tekniska Hogskola—Handlinger (Chalmers Univ. Technology—Trans.) no. 215, 1959, 16 pp.

An experimental determination is made of the power loss in a 360 journal bearing with an oil groove 90 before the load. The tests show good agreement with theory when the temperature rise is kept small. The results indicate the validity of considering the cavitated region to contain both oil and air when calculating the power loss. *(Abstractor: H. J. Connors)*

J. R. Belt, L. G. Schneider, "Are the Navy's Engine Oils Good-Enough for Their Latest Diesels?" SAE Paper no. 110A, January 1960, 15 pp.

The history of lubricant development for Navy diesel engines is reviewed. Three examples are given of highly loaded engines which suffered from piston pin failure using zinc-bearing oil. A change to non-zinc bearing oil solved the problem, but some doubt exists about the new diesels of the near future which will have still higher piston pin loads. Since stocking special oils for these few engines or using lower output engines are both logistically unsound, attempts are being made to improve and develop a single oil for all diesel engines. The use of a Neely Kinetic Oiliness Test Machine shows the non-zinc oil to be only slightly better than the zinc-bearing oil. A second problem has been port blockage on submarine diesels, a condition alleviated thus far only by Series 3 oils. The problem of a special oil for these ships exists since Series 3 oil tends to burn valves in other engines. The development of a single Navy oil for all engines is continuing. *(Abstractor: George C. Lawrason)*

N. A. Hunstad, R. A. Wilkins, R. E. Osborne, E. D. Davison, "Developing Transaxle Fluid". SAE paper 117A, January 1960, 37 pp.

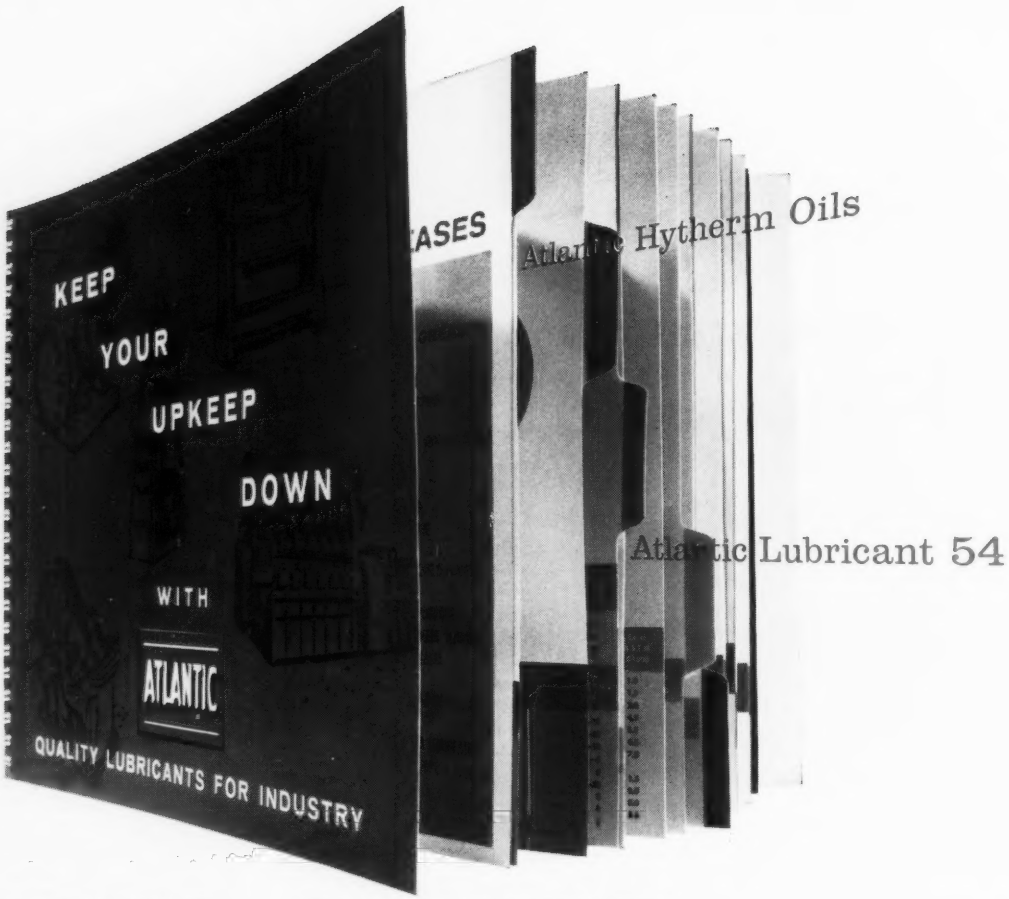
Reasons are presented for a single lubricant for both transmission and rear axle of transaxle cars. The histories of both automatic transmission fluids and hypoid gear lubricants are traced. The requirements of a transaxle fluid are listed. While manual transmission vehicles present no problems, the automatics with their clutch materials, seals, valving, and gears do. Tests on proposed fluids are made using both laboratory and road equipment, including special cars with a common oil system for both the rear axle and transmission. The importance of shear stability and the viscosity losses of various oils due to shear are discussed. The different tests used for evaluation of transmission, axle, and transaxle fluids are shown and described in the Appendix. Some 42 mineral-oil base and synthetic base fluids with various additives are evaluated with only three showing possibility of future development. The results of the tests are shown in chart form. The report concludes that considerable work remains to be done on transaxle fluids to achieve optimum results. Fifty-three references. *(Abstractor: George C. Lawrason)*

G. Niemann and H. Ohlendorf (Technische Hochschule München, Germany), "Power Loss and Heating of Spur Gear Drives". Z.V.D.I. v. 102, no. 6, 1960, 216-224.

The effect on friction loss and temperature rise, of speed, load, gear design and material, hardness, surface roughness, splash vs. jet oiling, oil viscosity are shown, based on rather few runs to demonstrate the effect of each change of conditions. Losses are principally dependent on speed and load. Bearing losses and no-load losses were separated from others. No-load losses and oil churning losses are generally small enough to be neglected. Tooth friction is roughly 1% of the power transmitted per mesh, at moderate loads and speeds. Equations developed for tooth friction and temperature rise are said to agree with results of experiments. *(Abstractor: E. A. Ryder)*

E. G. Ellis, "Problems and Progress in Two-Stroke Engine Lubrication," *Scientific Lubrication*, v. 11, no. 9, September 1959, pp. 12-18.

Some of the problems encountered in two-stroke cycle engine lubrication are discussed, as well as progress made toward the development of an ideal lubricant for this application. Special attention is given to oil-fuel mixing ability, oil quality, base oil type, oil additives, and a discussion of the properties of the ideal two-stroke lubricant. *(Abstractor: George C Lawrason)*



TWO PAGES...

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ATLANTIC

THE ATLANTIC REFINING COMPANY

Philadelphia, Pa. Providence, R.I. Syracuse, N.Y.
Charlotte, N.C. Pittsburgh, Pa.

Patent Abstracts

Compiled by Ann Burchick
Aluminum Co. of America

Lubricating Oil Thickened with a Metal Soap of an Alpha Sulfo-Fatty Acid, Patent No. 2,951,809 (J. W. Nelson, assignor to Sinclair Refining Co.) A grease composition consisting essentially of a lubricating oil base thickened with a soap of a fatty acid having twelve to twenty-two carbon atoms per molecule and a $-SO_3H$ radical attached to the alpha carbon atom and a metal selected from the group consisting of alkali metals and alkaline earth metals.

Process for Preparing Improved Lubricating Oils by Acid Treating Then Hydrofinishing the Lubricating Oils, Patent No. 2,944,015 (M. K. Rausch and W. B. Watson, assignors to Sinclair Refining Co.) A method for the production of a lubricating oil fraction of enhanced color, color stability and oxidation stability which includes the steps of distilling a naphthenic base crude oil to produce a raw lube distillate fraction having a SSU viscosity at 100 F. of from 50 to 6000 seconds, acid treating the raw distillate fraction with sulfuric acid having a strength of from 93-98 percent by weight in amount varying from 5 to 10 pounds of acid per barrel of oil for a raw lube distillate fraction having a SSU viscosity at 100 F. of 50 seconds to from 45 to 65 pounds of acid per barrel for a raw lube distillate fraction having a SSU viscosity at 100 F. of 6000 seconds, neutralizing the acid oil and washing the oil with water until free of sulfonates, and then hydrogenating the acid-treated raw lube distillate by passing it into contact with cobalt molybdate supported on alumina catalyst at a temperature of from 450 to 700 F., a pressure of from 400 to 700 p.s.i.g., and a weight hourly space velocity of from 5 to 20 while the distillate is in admixture with from 500 to 2000 standard cubic feet of hydrogen per barrel of oil and is sufficient to improve the color, color stability and oxidation stability of the oil whereby from 5 to 30 standard cubic feet of hydrogen are reacted per barrel of oil.

Lubricating Oil Composition, Patent No. 2,944,025 (J. A. Verdol, assignor to Sinclair Refining Co.) A lubricating oil composition consisting essentially of a major portion of a mineral oil of lubricating viscosity and a polyester compatible with said mineral oil in an amount sufficient to impart sludge-dispersing properties to the lubricating oil composition.

Anticorrosive Marine Diesel Lubricant, Patent No. 2,944,023 (I. S. Kolarik, assignor to Socony Mobil Oil Co., Inc.) An emulsion lubricant for marine diesels which comprises, by weight of the lubricant, between about 10 percent and about 50 percent water, between about 80 percent and about 45 percent mineral lubricating oil, having a Saybolt Universal viscosity of between about 45 seconds and about 100 seconds measured at 210 F., between about 1 percent and about 5 percent alkali-metal hydroxide, the number thereof being sufficient to effect a total base number in the lubricant of between about 10 and about 100, between about 1 percent and about 10 percent calcium mahogany sulfonate, between about 3 percent and about 7 percent of a mixture of polyhydric alcohol esters of high molecular weight acids obtained by controlled oxidation of petroleum wax, between about 0.5 percent and about one percent saturated fatty acid having between 16 and 20 carbon atoms per molecule, and between about 0.25 percent and about 0.5 percent lime, expressed as CaO.

Lubricants Containing Fatty Acid Esters of Saccharides, Patent No. 2,944,024 (A. J. Morway and W. E. Waddey, assignors to Esso Research & Engineering Co.) A lubricating grease composition comprising a major proportion of lubricating oil, about 5 to 30 wt. percent of an ester of one mole of a disaccharide and 1 to 3 moles of a C_{12} to C_{32} fatty acid and 5 to 40 wt. percent of an alkaline earth metal salt of a C_2 to C_6 fatty acid.

Anti-Wear Lubricating Oil Composition, Patent No. 2,944,020 (G. M. Verley, assignor to Sinclair Refining Co.) A lubricating oil composition consisting essentially of a major amount of a mineral lubricating oil containing minor amounts of oil-soluble nickel alkyl phenol sulfide in which the alkyl group contains about 8-24 carbon atoms, zinc dithiophosphate diester in which the ester groups contain about 4-14 carbon atoms, a sulfurized sperm oil anti-wear agent in an amount sufficient to contribute about 0.06 to 0.2% by weight of sulfur based on the mineral oil, a small amount of basic barium petroleum sulfonate sufficient to impart a barium content of about 0.2 to 2.0 percent by weight, said sulfide being present in an amount to provide about 0.01 to 0.20% of nickel and said dithiophosphate being present in an amount to provide 0.03 to 0.2% phosphorus based on the mineral oil.

Hydrocarbon Oils Having Improved Electrical Properties, Patent No. 2,951,751 (J. P. McDermott, assignor to Esso Research & Engineering Co.) A hydrocarbon oil boiling in the range between about 75 F. and about 750 F. having incorporated therein from about 0.00005% to about 0.5% by weight of a tetraalkyl ammonium salt of a C_2 to C_{10} unsubstituted hydroxy carboxylic acid, the alkyl groups of said salt each containing from 1 to about 24 carbon atoms.

Lubricating Oil Compositions Containing Polymers of Bis-(Beta Chloroethyl) Vinyl Phosphonate, Patent No. 2,956,952 (W. P. FitzGerald, A. H. Gleason, A. J. Morway and A. H. Matuszak, assignors to Esso Research & Engineering Co.) A lubricant composition comprising a major proportion of a lubricating oil and about 0.01 to 10.0% by weight, based on the total composition of a polymer having a molecular weight in the range of 1,000 to 3,500 of bis-(beta chloroethyl) vinyl phosphonate.

(*Continued on page* 352)

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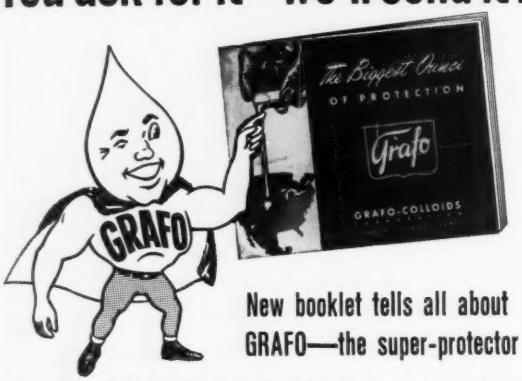

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PATENT ABSTRACTS

(*Continued from page* 351)

Lubricant Composition, Patent No. 2,953,527 (R. F. McKibben and A. H. Lipton, assignors to The National Cash Register Co.) A lubricant composition consisting of a mixture of the following ingredients, in parts, by weight:

Petroleum oil having a viscosity of approximately 150 Saybolt Universal seconds at 100 degrees Fahrenheit	78
Non-straight chain fractions of micro-crystalline petroleum wax	18
Aluminum stearate	4

Process and Composition for Preparing Sulfur-Chlorinated Cutting Oils, Patent No. 2,943,990 (M. K. Rausch and T. A. Francis, assignors to Sinclair Refining Co.) A method for producing a reactive oil product of low sludge forming tendencies from an extract oil obtained in the extraction of a lubricating oil stock with a solvent selective for aromatics to produce a primary raffinate oil and said extract oil, the step comprising extracting with a solvent selective for aromatics a material consisting essentially of said extract oil and a paraffin distillate, said extract being present in an amount of at least 25 volume percent of the total, to produce a secondary raffinate oil in a yield of about 20 to 90 volume percent of the material treated containing about 20 to 40 volume percent of the extract.

High VI Lubricating Oil and Process for Preparing Same, Patent No. 2,954,334 (C. E. Stoops and J. M. Day, assignors to Phillips Petroleum Co.) A process for treating a petroleum lubricating oil which comprises admixing said oil with an olefin having 2 to 5 carbon atoms in a ratio of 1-2000 parts of said olefin per 100 parts of said oil, and exposing the said admixture to a total dosage of ionizing radiation of 5×10^6 to 5×10^9 REP units, and thereby forming an oil having a higher viscosity index than the original lubricating oil, the said oil having a higher viscosity index being a product of reaction of said petroleum lubricating oil with said olefin.

(*Continued on page* 353)

PATENT ABSTRACTS

(*Continued on page 352*)

Open Gear Lubricants Containing Silicones, Patent No. 2,946,749 (L. W. Sproule and T. M. Rogers, assignors to Esso Research & Engineering Co.) A gear lubricant composition having a grease consistency consisting essentially of a major proportion of a viscous mineral lubricating base having an S.U.S. viscosity at 210 F. in the range of about 1,000 to 6,000, and in the range of about 0.05 to 1.5% by weight, based on the total lubricant composition, of a silicone composition consisting essentially of (1) dimethyl silicone polymer having an S.U.S. viscosity at 210 F. in the range of about 300 to 3,000, and (2) in the range of about 4.0 to 20.0 wt. percent, based on the silicone composition, of finely divided silica.

Lubricating Grease Thickened with Lithium Soap of Styrenated Fatty Acid, Patent No. 2,953,528 (J. B. O'Neil, assignor to Texaco, Inc.) A lubricating grease composition consisting essentially of a lubricating oil thickened to a grease consistency by a lithium fatty acid soap comprising at least 25 percent by weight of the lithium soap of a styrenated high molecular weight unsaturated fatty acid.

Corrosion Inhibitor Composition and Method of Preventing Corrosion, Patent No. 2,957,824 (W. M. Shamot, assignor to Nalco Chemical Co.) A corrosion inhibitor composition consisting essentially of in proportions by weight about 8-12% of a water and oil dispersible corrosion inhibiting compound, about 8-12% of an unoxidized mineral wax, about 3-12% of a water-insoluble solid alkylene polyamine-fatty acid polyamide dispersant, and a major proportion of a weighting material, in solid stick form.

Composition of Matter Consisting of a Microcrystalline Wax and 5-25% of an Aromatic Petroleum Extract, Patent No. 2,954,337 (E. J. Martin, assignor to Sinclair Refining Co.) A microcrystalline wax composition of improved lamination strength which essentially comprises a microcrystalline wax fraction base which has been deoiled to a hardness in terms of needle penetration at 77 F. of less than about 24 to 25 and about 5 to 25 weight percent based on the composition of an aromatic petroleum extract.

Stablization of Hydrocarbon Oils, Patent No. 2,953,444 (R. B. Thompson, assignor, by mesne assignments, to Universal Oil Products Co.) Hydrocarbon oil normally subject to deterioration in storage containing a stabilizing concentration of a compound selected from the group consisting of alkanoylaminohexahydropyrimidines and alkenoylaminohexahydropyrimidines.

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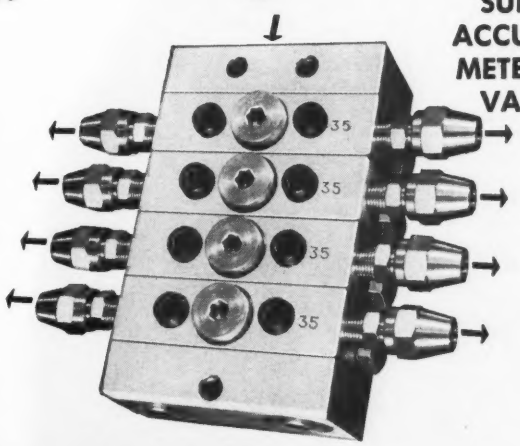

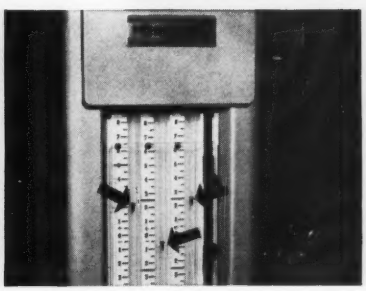

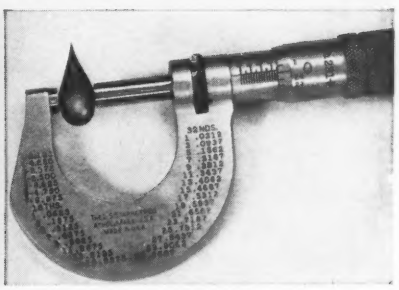

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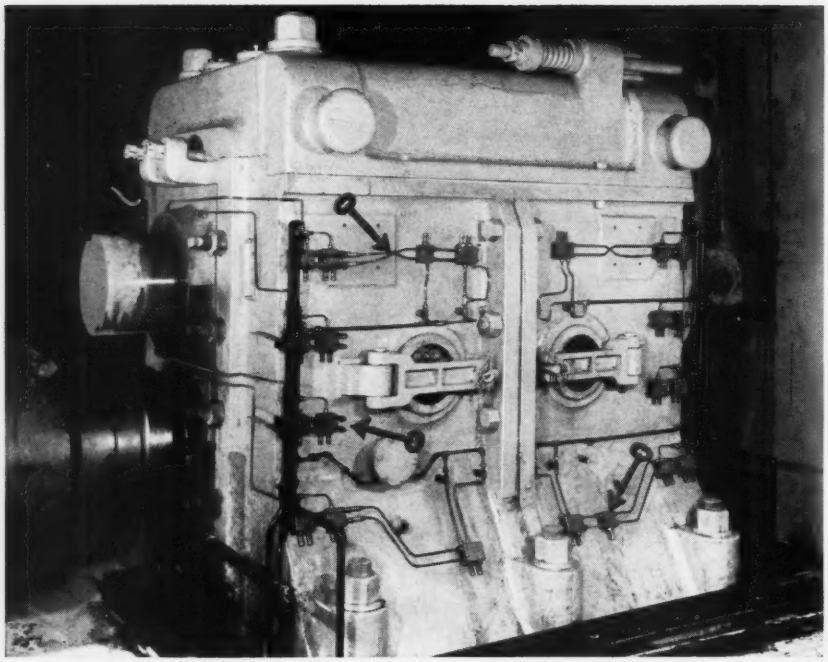

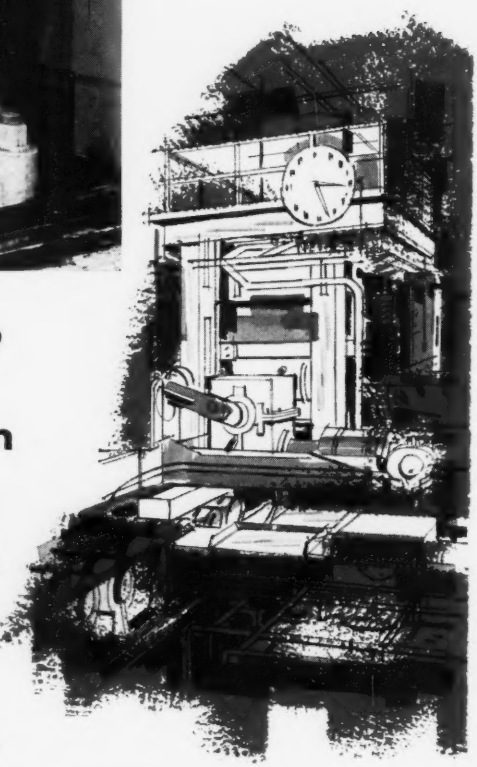

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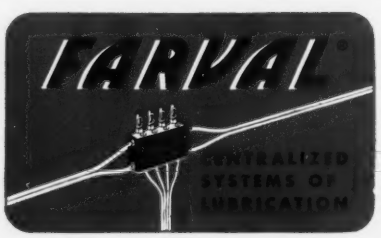
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